Marine Res.

1961
#1

DEPARTMENT OF AGRICULTURE AND FISHERIES
FOR SCOTLAND

LIBRARY
MAR 14 1961
FISH & WILDLIFE SERVICE

Marine Research
1961 No. 1

Trawl Performance

A Study Relating Models to Commercial Trawls

W. DICKSON, B.Sc.

EDINBURGH: HER MAJESTY'S STATIONERY OFFICE

PRICE 18*s.* 0*d.* NET

The following list shows the publications during recent years in the Marine Research series formerly issued by the Scottish Home Department. Details of earlier publications will be supplied on request by the Marine Laboratory, Department of Agriculture and Fisheries for Scotland, Victoria Road, Torry, Aberdeen.

MARINE RESEARCH SERIES

1956 1. The Effect of Electric Fields on Marine Fishes.
By Lt. Cdr. (Sp.) B. McK. Bary, M.Sc., Ph.D., R.N.Z.N. Price 7s. (7s. 3d.)

2. The Whiting (*Gadus merlangus* L.) in the North Sea.
By R. W. Ellis, B.Sc., and R. Jones, B.Sc. Price 5s. (5s. 2d.)

3. The Food and Feeding Habits of the Lemon Sole.
By Bennet B. Rae, M.A., B.Sc., Ph.D. Price 6s. 6d. (6s. 8d.)

4. Eggs and Larvæ of Haddock (*Gadus aeglefinus* L.) at Faroe.
By Alan Saville, B.Sc. Price 5s. (5s. 2d.)

5. Herring Rearing—II. The Effect of Temperature and other Factors on Development.
By J. H. S. Blaxter, M.A. Price 4s. (4s. 2d.)

1957 1. Herring Rearing—III. The Effect of Temperature and other Factors on Myotome Counts.
By J. H. S. Blaxter, M.A. Price 4s. (4s. 2d.)

2. Hydrography of the Faroe-Shetland Channel, 1927-1952.
By J. B. Tait, D.Sc., Ph.D., F.R.S.E. Price £5 5s. (£5 6s. 6d.)

3. The Food and Feeding Habits of Larval and Post-Larval Herring in the Northern North Sea.
By R. N. Bhattacharyya, M.Sc., Ph.D. (Calcutta) Price 7s. (7s. 4d.)

1958 1. The Ecology of Scottish Inshore Fishing Grounds—I. The Bottom Fauna of East Coast Grounds.
By A. D. McIntyre, B.Sc. Price 8s. 6d. (8s. 10d.)

2. The Effect of Artificial Lights on Fish and other Marine Organisms at Sea.
By J. H. S. Blaxter, M.A. and B.B. Parrish, B.Sc. Price 8s. (8s. 4d.)

3. *Lernaeocera obtusa* n.sp. Its Biology and its Effects on the Haddock.
By Z. Kabata, B.Sc. Price 8s. (8s. 4d.)

4. The Occurrence of Plerocercoid Larvae of *Grillotia erinaceus* (van Beneden) in Halibut.
By Bennet B. Rae, M.A., B.Sc., Ph.D. Price 10s. 6d. (10s. 10d.)

5. Herring (*Clupea harengus* L.) in Aquaria: I. Establishment.
By B. B. Parrish, B.Sc., J. H. S. Blaxter, M.A. and F. G. T. Holliday, B.Sc. Price 5s. (5s. 4d.)

6. Herring (*Clupea harengus* L.) in Aquaria: II. Feeding.
By J. H. S. Blaxter, M.A. and F. G. T. Holliday, B.Sc. Price 6s. (6s. 4d.)

7. Plant Production in the Northern North Sea.
By J. H. Steele, B.Sc. Price 10s. 6d. (10s. 10d.)

8. Lobster and Crab Fisheries in Scotland.
By H. J. Thomas, B.Sc., Ph.D. Price £1 12s. 6d. (£1 13s. 2d.)

9. The Occurrence of *Nicothoë astaci* Audouin and Milne Edwards on Scottish Lobsters.
By James Mason, B.Sc., Ph.D. Price 3s. (3s. 4d.)

1959 *Continued on page 3 of Cover*

(Prices in brackets include postage)

Obtainable from Her Majesty's Stationery Office
at the addresses on page 4 of cover or through any bookseller

DEPARTMENT OF AGRICULTURE AND FISHERIES
FOR SCOTLAND

MARINE RESEARCH
1961 No. 1

Trawl Performance

A Study Relating Models to Commercial Trawls

W. DICKSON, B.Sc.
Marine Laboratory, Aberdeen

EDINBURGH: HER MAJESTY'S STATIONERY OFFICE
1961

CONTENTS

	Page
INTRODUCTION	3
THE USE OF MODEL TRAWLS	4
Choice of Model Scale	4
Location and Method of Handling Models	5
General Validity of Model Results	6
A Preliminary Study of Model Drag	7
MODELLING THEORY	7
Modelling Rules	7
General Scaling Equation	10
The Effect of Change in Reynolds Number	11
Forces Acting on Otterboards	13
Shortcomings in Basic Knowledge	16
MODELLING PROCEDURE	16
A Method of Making Specification Drawings	16
General Description of Models	17
A Practical Example	17
IMPROVING THE SHAPE OF NETS	20
How a Bad Net was Turned into a Good One	20
A Detailed Discussion of the Aberdeen 30 ft Trawl	24
A Discussion of the Aberdeen 48 ft Net	31
A Discussion of the Granton Trawl	35
MEASUREMENT OF DRAG, SPREAD AND SPEED	39
The Need for these Measurements	39
"Mean of Means" Procedure	39
Results	39
Discussion	43
CONCLUSION	44
REFERENCES	45
APPENDICES	46
I. List of Twine Runnages Useful in Modelling	46
Runnage of Cotton Twines	47
II. The Amount of Twine in a Net	47
Appendix Table 1	48

The functions of the Scottish Home Department relating to Fisheries were transferred on 1st April, 1960 to the Depar of Agriculture for Scotland, which will in future be known as the Department of Agriculture and Fisheries for Sco

Trawl Performance

A Study Relating Models to Commercial Trawls

INTRODUCTION

When one thinks of fishing gear, and particularly of nets with their shapeless form on land compared that which they must assume when towed in the water, it is amazing that over the years, and in y forms all over the world, fishermen have managed to evolve such successful gear in the face of most sual difficulties. Chief among these difficulties is that of designing and working "in the dark", and has become greater as fishermen have dared more and shot their nets deeper in the water. Ever e nets were shot so deep as to be invisible, fishermen have had to imagine (or sense) the shape their would assume in mid water or on the bottom—just how it would operate and how fish would react . Even though their feeling for their craft has been keen enough for them to design nets surprisingly ient for the variety of purposes, it is difficult to believe that in many cases they could not be improved— e we know more about just how they operate in relation to the fish.

The Marine Laboratory at Aberdeen began a modest fishing gear programme with this objective. y methods used were echosounding over the top of another boat's gear and later underwater photo- hy by frogmen. The next steps were direct measurements on full-sized gear using engineering nods and, as this paper will show, the study of model gears, later modifying them and then modifying sized gears in the light of the information acquired.

The reasons for wishing to study model trawls are after all not so very different from the reasons for ying model ships, and that is a well established practice. The extent of our ignorance of trawl aviour made model work all the more pressing, always with the proviso that model results could be onably extrapolated to full size and naturally this too was uncertain at the beginning. A few theoretical iderations, however, based on rather inadequate data and a few practical considerations on how the els were to be made suggested that the scale chosen should not be anything like so small as that loyed on ship models. Another factor influencing the decision to start model work was that, at the , underwater cine-photography of full-sized fishing gear in action, having had one or two spectacular esses, appeared to be on the slope of diminishing returns. That this was so is no reflection on the arkable men, like the late Lieut.-Commander J. H. Hodges, who pioneered the field. Conditions in sh waters were simply against them.

n depths where there is enough light for cine-photography there are few fish of commercial importance r than flatfish, as can be seen in the Scottish Home Department film "Fish and the Seine Net" shot in . It has been possible to take some film of small trawls in action, but, as far as large trawls are con- ed, the poor visibility range obtainable in accessible and fishable British waters ruled this out on two its: firstly, danger to the divers and secondly, because no overall impression of the gear could be ed. In the clear waters of the Mediterranean, where the Ministry of Agriculture, Fisheries and Food "Trawls in Action" (1952) was shot, clarity and illustration were ideal but there were very few fish of sort, so that the study became one of shapes and dimensions as it is with models. Since the underwater ising of trawling gear by remote control and the mounting of time-delayed cameras on or near the are only just beginning to make their appearance, the study of model trawls also filled a gap in time should always be valuable in terms of economical modification and experiment.

When observations on models were commenced in 1954 it was as a try-out, with no certainty that it ld be a profitable line of investigation. The first scale chosen was one-eighth, so the models had to be d behind an outboard motorboat since these models with all their accoutrements are too big for any

but the largest and most expensive testing tanks. The comparison between these first models and f sized gear was sufficiently encouraging to warrant repeating and extending the trials in 1955 and 19 During the same period comparative information on the performance of the full-sized gear was gradua being accumulated aboard research vessels, with marked improvement in the instrumentation la during 1957 and 1958. By 1956 the Marine Laboratory had acquired a 15 h.p. motor coble which co tow quarter-scale models and these larger nets were used for all subsequent work up to 1958. This acco does not attempt a complete report of the model work, for that would indeed be a rambling docume but it is hoped that it will show some of the uses to which models can be put, how they can be made function effectively and something of the information (with its limitations) which can be gained fr their use.

THE USE OF MODEL TRAWLS

Choice of Model Scale

There are three reasons for observing fishing gear or models of it in operation:

1. to form an impression of the performance of the gear, to seek defects in its design and to try effect of alterations in design and rigging;
2. to make measurements on the gear so as to obtain a fuller appreciation of its hydrodynami performance;
3. to obtain information on the reactions of fish to the gear.

When the purpose of modelling is to look for bad features in the design of a net, it is ideally desira that the model should correspond mesh for mesh with the original and that the twine diameter sho also be proportionally reduced. Practical considerations, however, often force a compromise. Expe and the availability of suitable materials have to be taken into account and, if alterations are to be m to the setting of the net during the course of the experiment, the labour involved in altering a very sm mesh model must be considered. From this point of view a quarter-scale model with a half-scale me and an eighth-scale model with a quarter-scale mesh, are reasonable compromises. The implication such a departure from true modelling will be discussed later (p. 9). If, for either the first or more p ticularly the second purpose, a true scale model is required, then a scale of one-quarter is about smallest that can reasonably be used.

For the last of the above purposes small nets of some 20 ft headline length towed by the 15 h.p. co shown in Plate 1, are big enough to be quite effective fishing instruments, yet their size is not so gr that the overall perspective of the net becomes lost, which means that there is less likelihood of signific fish behaviour passing unnoticed. Their purpose implies that they should be made with meshes of size used commercially. It must be remembered, however, that fish may be more likely to react to model net as a whole rather than only to the part in closest proximity to them as would more likely the case with a big net. The species of fish encountered, too, are limited, being mostly flatfish and sand with an odd roundfish only on rare occasions. Since this account deals with modelling proper the reacti of fish to the models will receive only the briefest mention here.

In the section on modelling theory it is shown why there are good reasons for not making the sc too small, with a useful minimum of probably about one-eighth full size. At the other end of the sc the difficulties of making underwater observations and measurements on full-sized gear have b touched on in the Introduction. It is well to remember that, even where it is possible for frogmen observe large trawl nets in action, any reduction below normal towing speed which might be necess for the convenience or safety of the observers gives rise to problems analogous to those encountered modelling, in that the flotation to drag ratio is thereby upset. Some work has been done with a sm trawl of 40 ft headline length towed by a 60 h.p. vessel and this would correspond roughly to the h scale of a steam trawler's gear at a correspondingly reduced towing speed, but making measurem on the gear under such conditions was physically difficult. A scale of one-quarter has been found m convenient both from the point of view of making the models and observing them in action.

An important practical point is that the choice of model scale cannot be made altogether independently he engine power of the boat available for towing the models. (See Table I)

TABLE I

Guide to the engine power required to tow models

Trawl	Trawl drag	Speed	Tow rope h.p. to pull trawl gear	Power of towing vessel
size o ft Aberdeen net)	3·3 tons	$3\frac{3}{4}$ knots	84 h.p.	590 i.h.p. (old "Explorer")
f size (approx.)	11 cwt.	2 knots	7·5 h.p.	60 b.h.p. ("Kathleen")
rter-scale o ft Aberdeen net)	117 lb.	1·7 knots	0·6 h.p.	15 b.h.p. (motor coble)
th-scale o ft Aberdeen net)	10-30 lb. (indeterminate)	1·0 knots	0·03-0·09 h.p. (indeterminate)	$3\frac{1}{2}$ h.p. (outboard motor on dinghy)

Note: The manner in which trawls are named in Aberdeen is a rather arbitrary one and the dimension 30 ft. refers to the length of the groundrope from the end of the bosom to the wing tip.

The engine power and the boat towing the models may be either too small or too big. If they are too ll then the model isn't towed at adequate speed, but if they are too big then difficulty is encountered hrottling the engine sufficiently while still maintaining steerage way on the boat. The 15 h.p. motor le is for instance too big for the eighth-scale models and, while quite adequate for the quarter-scale del mentioned in the table, it had to have a special towing propeller fitted before it could cope with rter-scale models of an arctic trawler's gear.

ATION AND METHOD OF HANDLING MODELS

The general requirements of a location are a half mile stretch of clean smooth sandy bottom in ths between 3 and 6 fathoms, not too much tide, a shore reasonably free from surf, good sunlight an underwater visibility range of not less than 30 ft. These conditions are most difficult to satisfy in ttish waters and all the work described here was done where they fell short of ideal. In home waters e of the requirements are contradictory in that it is the strength of the tide and the surf which keep sand free from weed and again the time of year most suitable for sunlight and diving is not the time en the sand is free of weed. Other considerations are that a great deal of time can be saved for pro- tive work if the site chosen for operations is near an all-tide harbour where the loading of equipment be done expeditiously and where storage space for the equipment is available on the quav.

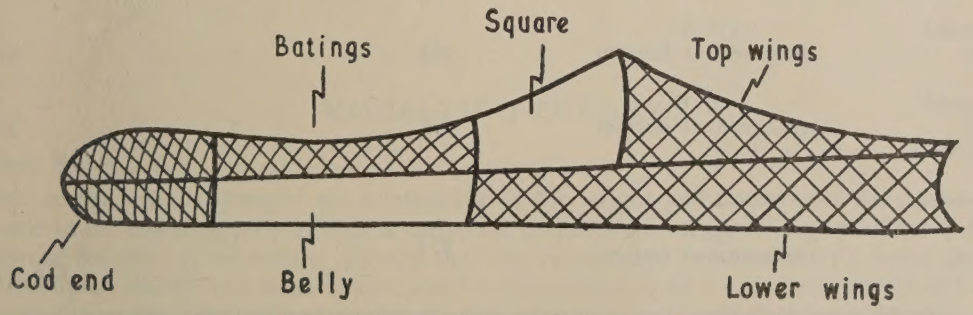


Fig. 1

The diving team comprises a minimum of five and preferably six persons. Two frogmen are under er together, for safety and efficiency, one making measurements on the gear and the other taking tographs. In order to help the frogmen on the spot and to facilitate subsequent inspection of photo- phs the tone pattern shown in Fig. 1 was eventually adopted for experimental nets.

Their attendant follows the divers' air bubbles in a rowing boat while the remaining men are in th motor coble which tows the models and the divers. It is not permissible for the divers to hang on to th models and they can not swim at towing speed for long. They therefore hang on to a towing rope trailin from the coble. This rope is weighted with chain some 30 yards ahead of the divers to prevent them bein ridden to the surface as they are towed along. The technique is now so well established that each membe of the team knows just what to do.

On an expedition of this sort there is a good deal of equipment to be maintained, diving gear, boa gear and engine, cameras, models and their measuring gear. It works best when each of these items the responsibility of a different member of the team. It is also important to develop the films day b day so that the progress of collecting evidence may be checked as it proceeds and repeated where necessar

General Validity of Model Results

At this stage it is perhaps useful to review the uses to which models can be put and to give som assurance that models do simulate the behaviour of full-sized gear.

Whereas the operational dimensions of models can be taken on strings and measuring sticks, th taking of corresponding readings on full-sized trawls requires some degree of instrumentation. In mo cases only a few spot checks between model and full-sized gear are possible. A general comparison of th appearance of the small Aberdeen net and a model of it can be had from Plates 2 and 3.

More models of the small Aberdeen trawl (the net used by the bulk of the Aberdeen fleet) have bee made than of any other trawl studied. It will therefore serve some purpose to compare the performanc of the various models of it with each other and with the original (Table II). The first model to be mad was an eighth-scale model where the meshes, which are $3\frac{1}{2}$ inches in the bulk of the original net, we reduced to 1 in. mesh, $\frac{1}{2}$ in. bar, in the model. The other two models were at quarter-scale. These ha their mesh size and twine diameter reduced to half-scale in one instance and quarter-scale in the othe i.e. the last was a true model.

Table II.

Table of comparison between performance of 30 ft net and the various models of it. *All values are scaled up to full size.* The rig is with 10 ft 0 in. × 4 ft 4 in. otterboards, 80 fm of warp aft, 10 fm sweeps and 20 ft spreading wires.

	Otterboard spread at full size	Net spread in feet	Headline height in feet	Warp pull in tons
30 ft Net of old "Explorer"	105 ft for 100 fm aft measured at surface	—	6*	3·25
$\frac{1}{4}$ scale model ($S_m = \frac{1}{2}$)	116 ft measured at bottom	$36\frac{1}{2}$	7	3·2
$\frac{1}{4}$ scale model ($S_m = \frac{1}{4}$) (true model)	118 ft measured at bottom	$37\frac{1}{2}$	7	3·4
$\frac{1}{8}$ scale model ($S_m = \frac{1}{3{\cdot}5}$)	93 ft measured at bottom	$37\frac{1}{2}$	6	2·3 up to 9 Indeterminate

*The flotation of old "Explorer's" net was on the low side compared with that of the models where the flotation was based on commercial practice.

In all cases the values vary from one drag to another and the above are no more than representati mean figures, but it is felt that these figures are a fair measure of the agreements and differences th may be expected.

The towing speeds for full-size, quarter-scale and eighth-scale were respectively and approximately knots, 1·5 knots and 1 knot.

It was felt that these results vindicated the use of models in which the mesh size and twine diameter e not reduced to the true scale, at least for most purposes (see p. 18). The only apparent difference tween the two quarter-scale models was in the shape of the codend, which billowed more in the true odel. This is because of the difference in twine thickness and pliability which becomes noticeable in e relative stiffness of the double-braided codends.

Preliminary Study of Model Drag

During 1957 a suitable stretch for towing the models was found on the Morar Sands and marker oys were laid. The buoy anchors were set 608 ft apart (one-tenth of a nautical mile) with a line of that ngth between them. After a little practice it became known at what r.p.m. to set the engine to give a wing speed of roughly 1·5 knots, the quarter-scale speed for 3 knots. The actual ground speed was termined by timing the tow between buoys on a stopwatch. The drag of the two warps was measured rectly on a spring balance. These data were collected at the same time as diving operations were in ogress. Naturally the effect of wind, tide and reading errors give a scatter to the plotted readings seen Fig. 2. Also included in this figure are spot values obtained on full-sized gear at sea as well as a selection results from the eighth-scale model. All results are normalised to full scale. For the quarter-scale models is is done by multiplying their speed by $4^{\frac{1}{2}}$ and their drag by 4^3 and for the eighth-scale by $8^{\frac{1}{2}}$ and 8^3 spectively. The reasons for this will be explained in the next section (p. 9).

Apart from the eighth-scale results which should all fall within the centre group, the results do fall to three distinct groups with fair agreement between models and the full-sized gear. It is a considerable p to be able to use the drag of quarter-scale models as a fair guide to the drag of trawling gear. The ghth-scale results show that a scale as small as this is no use for scaling up the drag forces, when the periments are done at sea where wind and tide cause an inordinate scatter of the readings. The wind d tide cannot be scaled down or eliminated and, therefore, even with quarter-scale nets, more scatter e to these factors than occurs with full-sized gear may be expected. Matters can certainly be improved better instrumentation at both full size and model scale, but it is unlikely that tests in the sea will be nsistent enough to determine accurately the scale effects which must almost certainly be present. om the foregoing results there is not even a hint of what they might be.

It was with these thoughts in mind that it was decided to make a more careful comparison of the drag models and full-sized gear, particularly as better instruments were becoming available for the measure-ent of both drag and speed. Such a study forms the subject matter of the last section.

MODELLING THEORY

odelling Rules

As soon as the scale is changed the relationship of the weight and flotation of the net vis-á-vis the rtia forces of lift and drag on otterboards and net is in question. A scale towing speed has to be chosen restore the balance. A secondary effect is that the relationship between inertia forces and viscous ces is also upset, though to a lesser extent, and for this balance to be restored an entirely different scale ed would be necessary. Both sets of conditions cannot be met at once and the greater the scale reduction greater the discrepancy between the performance of the model and the original.

As a model is scaled down from the original all weights and floats, being dependent on volume, decrease by the cube the scale, while all lifts and drags due to water flow, being dependent on surface areas, decrease by the square of the le. The requirement for the model to have the same shape under water as the original is that the ights and flotation bear the same ratio to the lifts and drags in both cases.

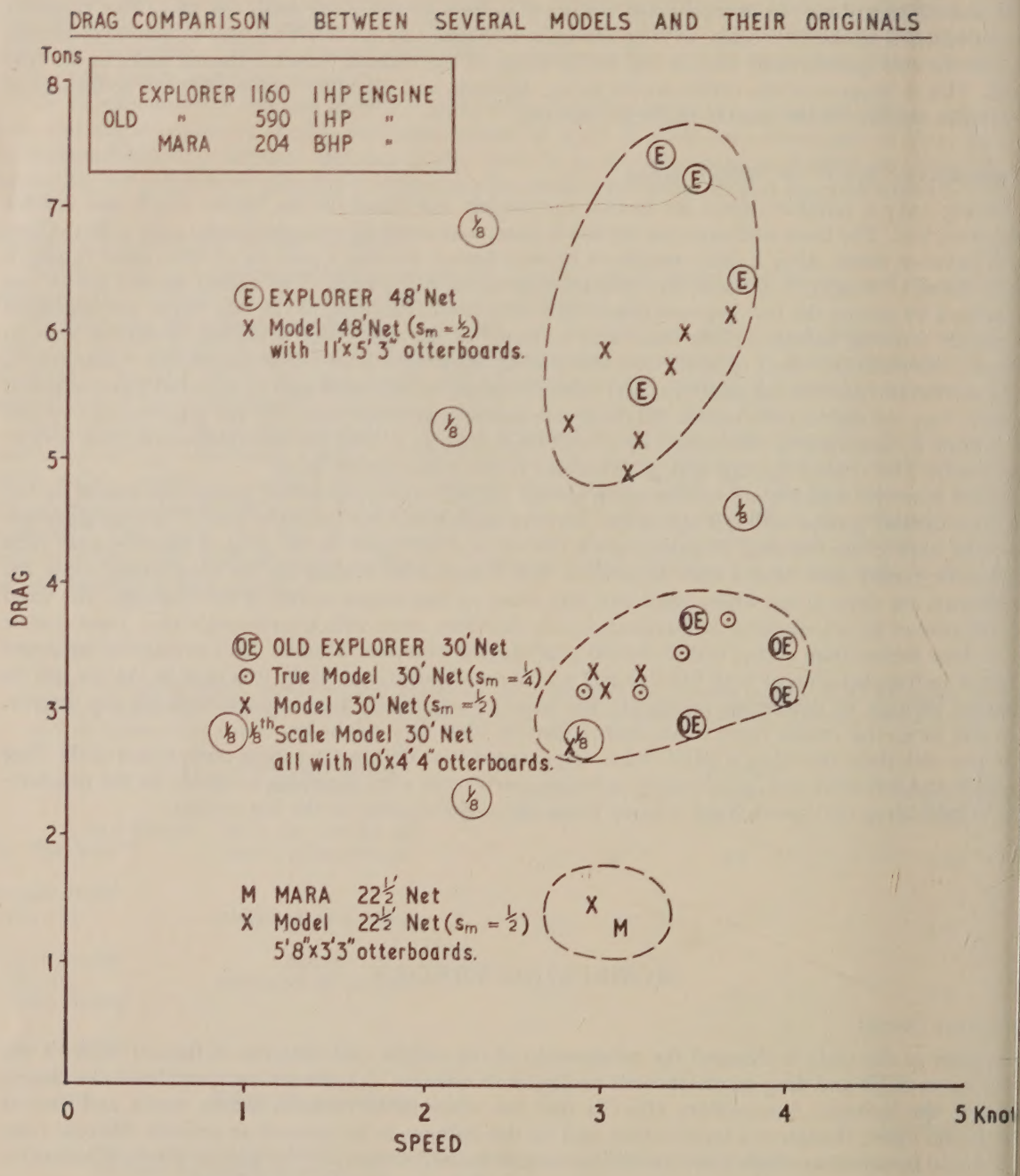

DRAG COMPARISON BETWEEN SEVERAL MODELS AND THEIR ORIGINALS
Tons
EXPLORER 1160 IHP ENGINE
OLD " 590 IHP "
MARA 204 BHP "
E EXPLORER 48' Net
X Model 48' Net (sm = 1/2) with 11'x5' 3" otterboards.
OE OLD EXPLORER 30' Net
⊙ True Model 30' Net (sm = 1/4)
X Model 30' Net (sm = 1/2)
1/8 1/8th Scale Model 30' Net
all with 10'x4' 4" otterboards.
M MARA 22 1/2' Net
X Model 22 1/2' Net (sm = 1/2)
5'8"x3'3" otterboards.
DRAG
SPEED
0
1
2
3
4
5 Knots
8
7
6
5
4
3
2
1

Fig. 2

Thus

F and W are proportional to l^3	where F and W are flotations and weights in the original and where l is a unit of length.
L and D are proportional to $l^2 v^2$	where L and D are lifts and drags due to water flow in the original and where v is the towing speed
F_s and W_s are proportional to $(sl)^3$	where F_s and W_s are flotations and weights in the model, where l is as before and s is the scale.
L_s and D_s are proportional to $(s\,l)^2 (s^{\frac{1}{2}} v)^2$	where L_s and D_s are lifts and drags due to water flow in the model.

It may be seen that for $\frac{L}{L_s} = \frac{D}{D_s} = \frac{F}{F_s} = \frac{W}{W_s}$ there are several requirements.

1. All dimensions of length must be reduced to scale.

2. Floats and sinkers must be of the same density in the model as the original; otherwise the change in flotation or weight will not be proportional to the cube of the scale. Netting twine should also be of the same material; otherwise there is a change in density, and here arises a difficulty. Most big nets are made of manila twine, which cannot be obtained thin enough for model making, hence the usual material for model making is cotton twine. Although there is no very definite agreement about specific gravities of twine the following figures may be used;

Manila (greenproofed with cuprinol)	s.g. 1·29
Cotton (greenproofed with cuprinol)	s.g. 1·34
Nylon	s.g. 1·12

3. The speed of towing must be reduced by the square root of the model scale. It follows that in operations such as seining, where time is also a factor, the timing of operations must also be scaled down by the square root of the scale. If the normal towing speed of trawls is taken as 3 knots, then

$\frac{1}{2}$ scale towing speed $= 3/\sqrt{2}$ or about 2 knots

$\frac{1}{4}$ „ „ „ $= 3/\sqrt{4}$ or $1\frac{1}{2}$ knots

$\frac{1}{8}$ „ „ „ $= 3/\sqrt{8}$ or about 1 knot

4. It is implicitly assumed that the lift or drag due to water flow changes proportionally with the square of the velocity, but this will only be so over a limited range of change in scale and change in speed. This will be discussed later (p. 11).

As has already been indicated it is not always possible and sometimes not even desirable or necessary obey all these rules. It is necessary, however, to understand in each case just how they are being broken d the direction of the resulting bias, so that either it may be allowed for or measures taken to overcome Let only one of the probable compromises be considered, the one on which most of the models described re were made, where mesh and twine size were reduced less than by the scale.

Let l be the length of twine in the original
R „ „ runnage „ „ „ „
ρ „ „ density „ „ „ „
W „ „ weight „ „ „ „
d „ „ diameter „ „ „ „
A „ „ projected area „ „ „ „
(similar letters with the subscript 's' refer to the model)
S „ „ scale of the model
S_m „ „ mesh scale and
S_d „ „ twine diameter scale

Then $W = \frac{l}{R}$ (1)

$A = ld$ (2)

$W_s = \frac{l_s}{R_s} = \frac{1}{R_s}\frac{S^2 l}{S_m}$ (3)

$A_s = l_s\, d_s = \frac{S^2 l}{S_m} S_d\, d$ (4)

and $\frac{1}{R} = \rho\frac{\pi}{4} d^2$ approx., $\frac{1}{R_s} = \rho_s\frac{\pi}{4} d_s^2$ approx. (5)

Hence $S_d = \sqrt{\frac{\rho R}{\rho_s R_s}}$ (6)

When the model scale is a true one

$$W = \frac{l}{R},\ S = S_m = S_d,\ R_s = \frac{R}{S^2},\ \rho = \rho_s$$

$$A = ld$$

$$W_s = S^3\frac{l}{R} \text{ and}$$

$$A_s = S^2 ld$$

but now take the simple case

$$S = \frac{1}{4},\ S_m = S_d = \frac{1}{2},\ \rho = \rho_s,\ R_s = \frac{R}{S_d{}^2}$$

$$W_s = \frac{S_d}{R} S^2 l \text{ and}$$

$$A_s = S^2 ld$$

The area of twine projected to the water flow is correctly scaled but the model is twice as heavy as it should be, and this has to be balanced by increased flotation. Where, as is often the case, the model cannot be made of the same material as the original, similar effects occur.

General Scaling Equation

Modelling is only a rather extreme form of scaling. Essentially the same problem is met in scaling a known net up or down in size to match a boat of greater or lesser horse power and to match bigger or smaller otterboards. It is also met when a decision is required on changing the mesh size or twine strength of a net.

In ringing these changes there are several factors to be considered. Firstly, the drag of a net depends not on headline length or distance round the mouth but on net size or area so there is an area factor to be manipulated. Secondly, there is a mesh size factor to be dealt with and clearly the bigger the mesh the smaller the drag. Thirdly, there is a twine factor which depends on twine diameter and not directly on the weight or runnage of the twine. Lastly, there is a towing speed factor.

A general equation embodying these factors can be built up as follows:

$$\frac{D_m}{D} = \left(\frac{M_m}{M}\frac{N_m}{N}\right)^2 \times \left(\frac{M}{M_m}\right) \times \left(\frac{\rho}{\rho_m}\frac{R}{R_m}\right)^{\frac{1}{2}} \times \left(\frac{v_m}{v}\right)^2 \quad \ldots\ldots (7)$$

Drag Ratio	Area Factor	Mesh Factor	Twine Factor	Speed Factor

here

D=standard drag

M=standard mesh size

N=standard number of meshes round the mouth

ρ=standard specific gravity of twine

R=standard runnage of twine

v=standard towing speed

subscript 'm' denotes the modified set of conditions

here are limitations to the use of this formula. It applies only to nets of the same shape, i.e. to bigger naller versions of the same net, and it applies even then only when the bigger or smaller version is d to the same proportion of the headline length and height or more strictly when the fishing shape same. It must be realised that the formula only compares one set-up with another: therefore some- e along the scale conditions must be known. Two other points should be borne in mind when using tells nothing of the new flotation or sinkers that should be chosen for the scale version, but fishermen quickly achieve a satisfactory balance in practice and the same can be said for model makers, although hoice affects the drag to some extent. It also continues to assume that the drag of sheet netting, but of the gear as a whole (see p. 39), is proportional to the square of velocity. Even if the formula is not ly accurate it has shown itself to be quite good enough for tackling the scaling problems encountered t design. By this is meant that nets scaled according to the formula behave in a reasonably predictable bearing in mind the variability of the measurements that can be made on the original and scaled ons under sea-going conditions. Let us now question the assumption that the drag is proportional ie square of the velocity.

Effect of Change in Reynolds Number

hat hydrodynamic drags and lifts should be proportional to the square of the velocity is a funda- al and theoretically derived result which in practice is not strictly applicable. Rather than alter ower indices away from the square law the usual practice is to express drag or lift in a form such $=C_D A v^2$,

where D=drag
C_D=drag coefficient
A=area (either total or projected according to circumstances)
v=velocity,

to alter the drag coefficient to fit. The change in drag coefficient is usually plotted against Reynolds ber, R_n being a dimensionless number, a composite of the various dimensions which cause the drag icient to vary. $R_n=\frac{vl}{\eta}$ where

is an arbitrary length unit such as say the diameter of the floats or the twine diameter.

) is the kinematic viscosity and $\eta=\frac{\mu}{\rho_m}$ where

is the viscosity of the medium

ρ_m is the density of the medium

o long as R_n remains constant it can be taken that the conditions of the water flow round the ersed body remain the same, i.e. the ratio of inertia to viscous forces is the same. It is apparent at that in model tests in the sea η cannot be altered and therefore for constant R_n the velocity of the el should be inversely proportional to the scale. It has been said already, however, that for constant tion to drag ratio the velocity of the model should be directly proportional to the square root of the . Since both conditions cannot be met at the same time some changes of Reynolds number must ccepted. The question is what change of drag coefficients does such a change in Reynolds number g? Fig. 3 shows that for spherical headline floats there may be little change of drag coefficient

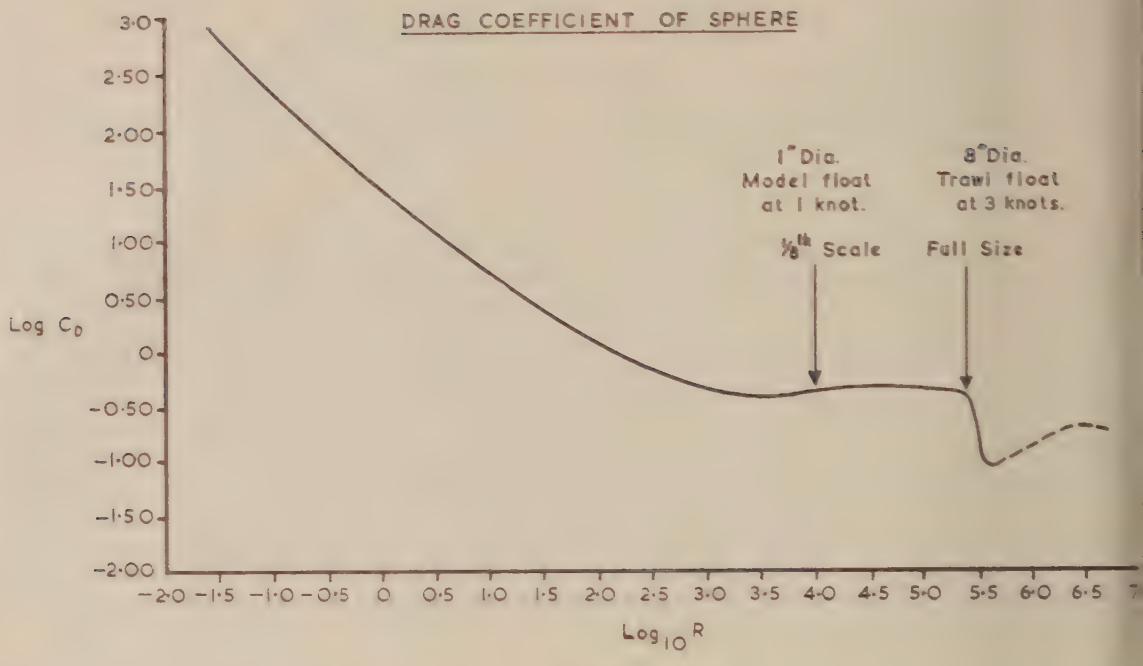

DRAG COEFFICIENT OF SPHERE
1" Dia. Model float at 1 knot. 1/8th Scale
8" Dia. Trawl float at 3 knots. Full Size
Log C_D
3·0
2·50
2·00
1·50
1·00
0·50
0
−0·50
−1·00
−1·50
−2·00
−2·0 −1·5 −1·0 −0·5 0 0·5 1·0 1·5 2·0 2·5 3·0 3·5 4·0 4·5 5·0 5·5 6·0 6·5
Log10 R

Fig. 3

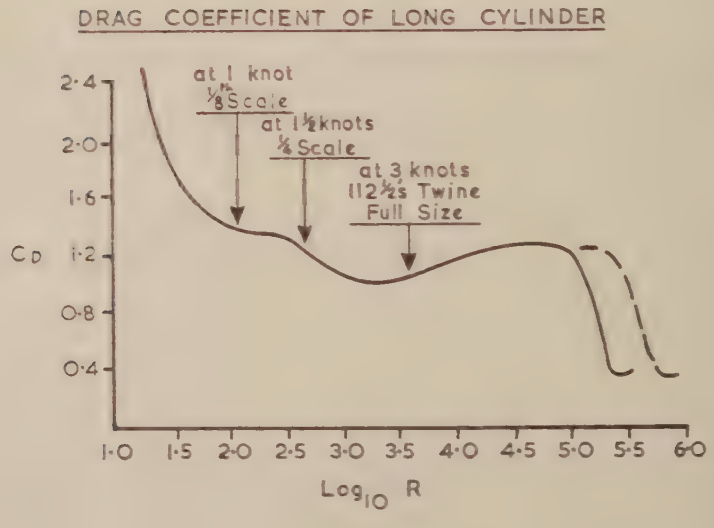

DRAG COEFFICIENT OF LONG CYLINDER
at 1 knot 1/8 Scale
at 1½ knots ¼ Scale
at 3 knots 112½'s Twine Full Size
C_D
2·4
2·0
1·6
1·2
0·8
0·4
1·0 1·5 2·0 2·5 3·0 3·5 4·0 4·5 5·0 5·5 6·0
Log10 R

Fig. 4

stein, 1938a) between the full-size and eighth-scale at scale towing speed, but it is also possible n the full-sized net the proximity of the headline to the balls and their method of attachment to y change the flow pattern so that the drag coefficient decreases to values given in the sharp dip in raph.

he case of the balls is taken for illustrative purposes, because the drag coefficient of a sphere over le range of Reynolds number has been thoroughly investigated. The drag of the floats would in ase amount to only a very small part of the total drag. From the point of view of change of shape en model and original this, then, is not likely to be of much importance, but what of the change ag coefficients for the netting twine and the otterboards?

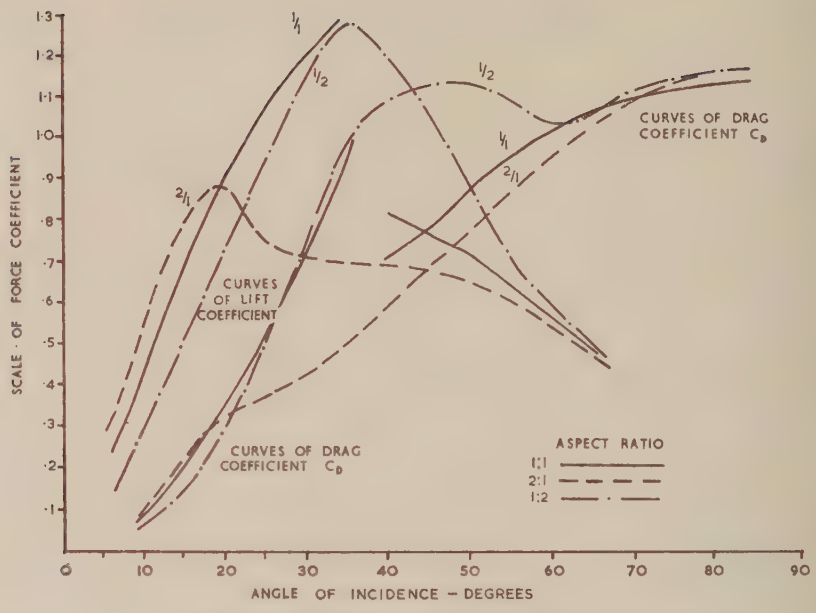
ar less is known about how sheets of netting behave over a wide range of scale and speed, but, for of anything better, it might be assumed that the drag coefficient for the total would vary in the same as that of the twine of which it is made and that twine is in the form of a long cylinder. There are al doubtful factors in such an assumption. Netting twine is not smooth and, moreover, the surface ness varies with the material. As has already been mentioned, it will not always be possible to make del of the same material as the original. Netting twine is not infinite in aspect ratio; there are all nots, and lastly most of the twine in a net is not normal to the stream. The variation of drag co- nt of a smooth cylinder of infinite aspect ratio and normal to the stream (Goldstein, 1938b) is n in Fig. 4. The graph illustrates the probability of an appreciable increase in drag coefficient in a eighth-scale model (i.e. with twine and mesh size also reduced to one-eighth). It is this as well as urely physical difficulty of making accurate small-scale nets that puts a lower limit on scale size. Reynolds number for the twine used in the making of the models during the experiments ranged 240 for the single eighth-scale model to 1100 for the quarter-scale models of the arctic trawls.

es Acting on Otterboards

nformation on the lift and drag of otterboards is better, but hardly complete. A full-sized board 10 ft towed at 3 knots would have a Reynolds number of about $3{\cdot}5 \times 10^6$. Gawn (1943) gives some data at boards of low aspect ratio at a Reynolds number of about 4×10^5. These boards (corresponding out 1/12th scale) were towed at up to 5 knots apparently without much change in the lift and drag cients in that speed range. These data cover the model range up to quarter-scale quite well. Some of n's graphs are reproduced in Figs. 5 and 6.

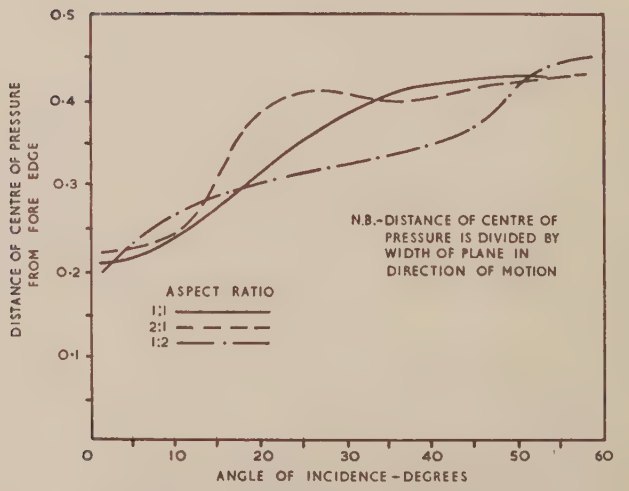
fore recently Yakovlev (1955) has produced results taken from tests in a wind tunnel where it is ble to test model otterboards at the correct Reynolds number. A selection of these results plotted e same scale as Gawn's is given in Figs. 7 and 8. In these experiments the bottom edge of the oard was rested on a flat surface or screen to simulate the presence of the bottom and it can be that its presence reduces the maximum lift and drag obtainable as well as shifting the point of num lift to a lower angle of incidence. In fact he suggests that normal otterboards should not have gle of attack greater than 25-30°. The accoutrements of the trawl board also reduce its lift and ase its drag somewhat. The introduction of the screen serves to push the centre of pressure farther aft. here remains another factor to be considered and that is the frictional effect of the ground over n the otterboard is towed. This not only adds to the drag of the board but can, as a very simple iment towing a model otterboard over a gravel path on dry land will show, increase the lift or ing force as well. Of these forces we have only the roughest assessment and indeed they must be ult to determine because they must be expected to vary not only with the nature of the bottom lso with the angle of declination of the warp next to the otterboard as a greater or lesser weight of oard is eased off the bottom. The frictional forces on the otterboard must act on that part of the nost strongly in contact with the bottom. That may be the heel or toe dependent not only on the he board is rigged but also on the interplay of warp length, depth and towing speed. The effective e of pressure is thus likely to be somewhat modified from that determined when the board is at rest wind tunnel experiment.

he most that can be expected for these frictional forces would be a few representative figures to help erboard calculations.



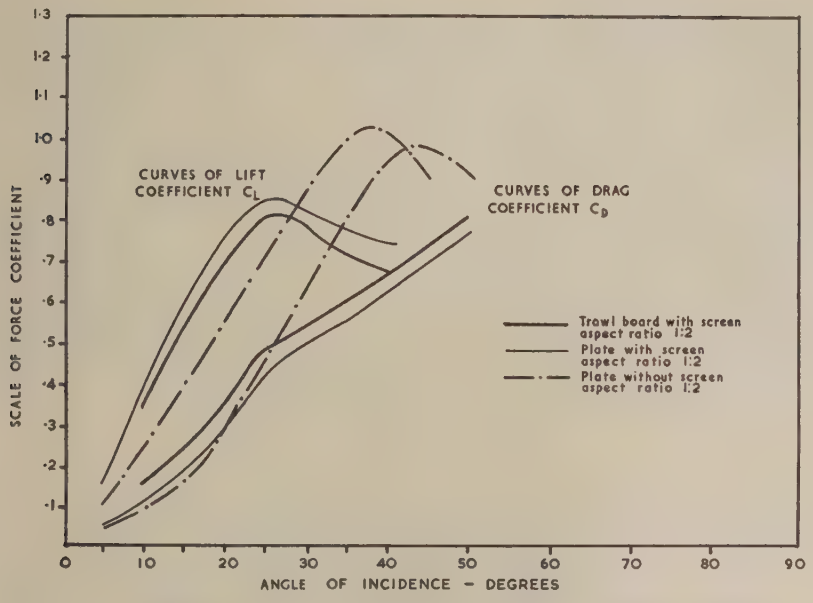
FORCES ON RECTANGULAR AND SQUARE PLATES
(FROM GAWN)

Fig. 5



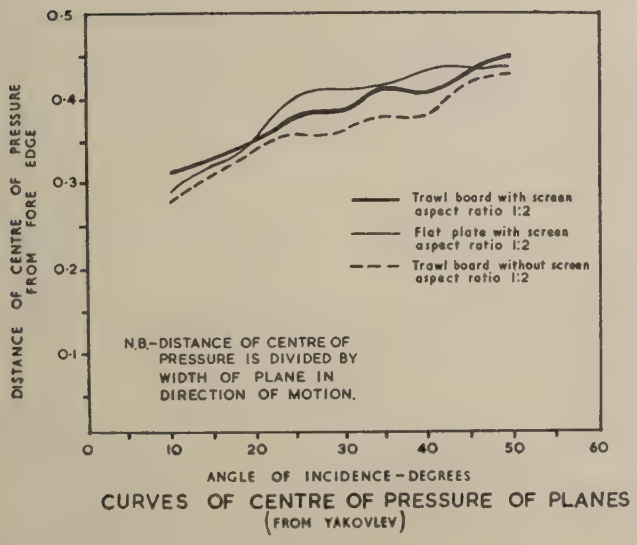
CURVES OF CENTRE OF PRESSURE OF PLANES
(FROM GAWN)

Fig. 6



FORCES ON RECTANGULAR PLATES & TRAWL BOARD
(FROM YAKOVLEV)

Fig. 7



CURVES OF CENTRE OF PRESSURE OF PLANES
(FROM YAKOVLEV)

Fig. 8

Shortcomings in Basic Knowledge

There is no reason to suppose that the force coefficients of sheet netting and otterboards behave in exactly the same way with change of Reynolds number and so, since trawling gear is not a rigid structure, small discrepancies between operating dimensions of models and full-sized gear may be expected. Naturally, the greater the change of scale the greater the discrepancies, and until more is known about these scale effects it will be safer to use as large a scale as possible.

It should now be apparent that there are certain gaps in our basic knowledge and that these are impeding progress and limiting the accuracy with which predictions from scale models can be made. The tackling of such fundamental work is therefore urgent. A whole series of data is now required on the drag of sheet netting and on scale effects. More precise information is required on the hydrodynamic and frictional forces acting on trawl boards at both full scale and model scale. The change of drag caused by the change of spread and gape of a model net should also be investigated experimentally. The experimental side of this work will, moreover, have to be done in testing tanks where sufficient accuracy is obtainable. When these things are done it should be possible to design a net, be it model or full size, from scratch and with its operating dimensions and drag predetermined.

MODELLING PROCEDURE

A Method of Making Specification Drawings

A net when laid out has no very definite shape; even when hung up by strings for demonstration it does not bear a close resemblance to its shape when being towed through water. All this makes schematic illustration of a net a difficult matter to resolve satisfactorily especially since it is desirable that its features be shown in a quantitative way.

Engineers have for a long time used standard methods when making their drawings so that they can be understood by all, but there is no such tendency towards standardisation of the drawings and specifications of nets. Each firm or designer draws nets as it or he thinks best. Some of the drawings are made in speculative fashion, in an attempt to show the net in the fishing position with a few dimensions added for good measure. It is rare for any of these drawings and specifications to be complete, many of the details simply being carried in the heads of the makers. It is not easy to tell at a glance from such drawings what the salient features of the nets are or how they compare in shape with other nets, and yet it should be possible to make such drawings.

When a model net is to be made it is desirable that a glance at the drawings should show, when compared with those of the original, whether or not the model is a fair replica. The scales can be so chosen that drawings of both model and original are the same size. By the use of tracing paper the two can be compared and a very fair idea obtained of the accuracy of the shape of the model. Similarly, when comparing two different commercial nets in this way their salient features stand out at once.

One set of rules may be as good as another, but the following have been found useful in practice (Dickson, 1957):

1. All lengths are true lengths with the netting stretched, but any lengthways slack which is set in is noted on the drawing and indicated by an irregular line in the edge of the panel concerned.
2. All widths are taken by setting the meshes in by the half, e.g. 120 meshes across at $1\frac{1}{2}$ in. mesh set into $120 \div 2 \times 1\frac{1}{2} = 90$ in.

Such rules give the drawings of a net a "stepped" appearance which the net does not of course have in practice, but they do have the merit of showing directly where the lateral slack and tautness is set into the net. The drawings do not cover the setting of the nets to their ropes. Such details may be added in note form. All specifications in this report are drawn according to these rules.

Provided that the same drawing rules are always observed, the patterns which turn out to be good and bad practice can be remembered. This helps considerably in the designing of nets.

ERAL DESCRIPTION OF MODELS

All the quarter-scale models except one were made on the principle of reducing both mesh size and ne diameter by half and at the same time reducing the number of meshes both in length and breadth alf the number in the specification of the original. Ropes and rigging were reduced to the true scale ne-quarter. The exception was a true model of the Aberdeen 30 ft trawl where both mesh size and ne diameter were also reduced to the true scale of one-quarter and the number of meshes in length breadth kept the same as in the original. The nets where the mesh size is reduced to only a half of the original were all hand braided and thus, so long as they are correctly braided on a spool of correct size, there can be no question of their not corresponding to the shape of the originals. Greater promises were enforced when making the eighth-scale models as these had to be wholly or partly le out of sheet netting of such twine size and mesh as was readily available.

The twine diameters for the models can be fairly accurately chosen from Appendix I. A good check he accuracy of modelling of a net is to compare the weight of the model with what its weight should when calculated from the weight of the original.

RACTICAL EXAMPLE

Let us now deal thoroughly with the Aberdeen 30 ft net and three different models of it.

Since the pattern of a net can be split up into a series of trapeziums, as seen from any of the specifica- drawings, it is not difficult to estimate the amount of twine in a net (see Appendix II). The weights ne auxiliary gear are given here as is the flotation typical for that net. With these values the weights ne models are compared and the flotation for the models discussed.

Table III gives the weights of the net parts of a 30 ft trawl.

TABLE III

The weights of the net parts of a 30 ft trawl

	Calculated from length of twine and knottage factor	Figures obtained from two net-making firms	
Pair of Top Wings	17½ lb	15 lb	20 lb
„ „ Lower „	24½	24	41
Square	36	32	28
Batings	48	37	38
Belly	31	29	40
Codends	78	70	60
	235	207	227
		Mean 217 lb	

The weight of the trawl rigged with ropes may be taken as 323 lb which is 50% above the weight of net parts. The weight of the net and its accessories are as follows:

Net Parts	217 lb	323 lb
Ropes and Rigging	106 lb	
Fishing Lines	23 lb	
Rope Bosom	224 lb	488 lb
1×30 ft Rubber		
Groundropes	264 lb	

Typical flotation is (6 + 20 + 6) × 8 in. floats at 6·9 lb lift each = 220 lb. The weight of the net and s (all manila) in water = 323 (1·29 − 1) ÷ 1·29 = 72 lb. Hence nett upthrust = 148 lb.

Now consider the *quarter-scale model* with the meshes reduced to only half-size and made in 12/15s twine.

$$S_m = \tfrac{1}{2},\ S_d = \sqrt{\frac{\rho R}{\rho_s R_s}} = \sqrt{\frac{1\cdot29}{1\cdot34}\cdot\frac{112}{440}} = \frac{1}{2\cdot02}$$

so that the twine is 1% too thin.

Weight of model netting $W_s = \frac{1}{R_s}\frac{S^2 l}{S_m}$

Weight of true model netting $W_{ST} = \frac{1}{R} S^3 l$

$$\frac{W_s}{W_{ST}} = \frac{R}{R_s}\cdot\frac{1}{S\ S_m} = \frac{112}{440}\cdot\frac{4\times2}{1} = 2\cdot04 \text{ times too heavy.}$$

By this compromise in modelling the net should be twice as heavy as a true model, so the modelling err is only 2% in the choice of twine selected. The errors in the actual runnage of the twines compared wi their stated values can be considerably greater than this.

The estimated weight of the model from the original is

$$\frac{217}{64}\times2\cdot04 + \frac{106}{64} = 6\cdot9 \text{ lb netting} + 1\cdot7 \text{ lb ropes} = 8\cdot6 \text{ lb.}$$

The actual weight of the model is 7·0 lb netting + 1·1 lb ropes = 8·1 lb.

The estimated weight of trawl accessories is $\frac{488}{64} + \frac{23}{64} = 7\cdot6$ lb footrope + 0·36 lb fishing lines.

The actual weighed weight of model accessories is 4 lb footrope + 4·5 lb of chain added + 0·4 lb fishi lines.

The groundrope with chain was then a little too heavy but this appeared to be necessary.

Now comes the task of deciding what the flotation of the model should be. Returning to the origin net for the moment, the flotation is 220 lb so that for a true model the flotation should be 220/64 lb 11 × 5 oz floats. Since the netting of this model is about twice the weight of a true scale model it is cle that its flotation ought to be increased, but by how much? Certainly not by twice as much as the very fi trial quickly showed. It speaks for the increased accuracy of work with the quarter-scale models that t discrepancy showed up as soon as these larger nets were used. The weight of the original net in wa would be 94 lb leaving a nett upthrust by the floats of 220—94 = 126 lb. Now, returning to the mo made in cotton (s.g. 1·34) mounted on manila ropes (s.g. 1·29), the weight of model under water worki on its measured weight in air should be

$$7\cdot0\ (1\cdot34-1)\div1\cdot34 + 1\cdot1\ (1\cdot29-1)\div1\cdot29 = 2\cdot0 \text{ lb.}$$

Hence flotation required should be

$$2\cdot0 \text{ (i.e. weight of model in water)} + \frac{148}{64} \text{ (i.e. scale upthrust)}$$

$$= 2\cdot0 + 2\cdot3 = 4\cdot3 \text{ lb or } 14\times5 \text{ oz floats.}$$

In practice the best flotation to match the gape of the original net turned out to be 13 × 5 oz floa between the 11 for a true model and the 14 as calculated above, but what justification can be fou for such a compromise? It could be argued that only the upper half of the net is buoyed up by t floats whereas the lower half is held down by the groundrope. The argument would then run follows. The weight in water of the upper half of the original net would be 36 lb, leaving a nett buoyan of 220 − 36 = 184 lb. Then for the model we have

$$1\cdot0 \text{ (weight of upper half of model under water)} + \frac{184}{64} \text{ (scale upthrust)}$$

$$= 1\cdot0 + 2\cdot9 = 3\cdot9 \text{ lb or } 12\tfrac{1}{2}\times5 \text{ oz floats.}$$

This line of argument also held satisfactorily for the models of the Granton trawl, large Aberdeen 3 ft trawl and small 22½ ft net.

It should be clearly understood that arguments of this sort arrive at empirical rules for achieving ractical results and that these rules cannot be blessed with the name "laws of nature".

With a true model compromises of this sort should not be necessary. How far does this turn out to e so? The true model of the 30 ft net was made in 36/12s cotton.

$$S_m=\tfrac{1}{4},\ S_d=\sqrt{\frac{\rho}{\rho_s}\frac{R}{R_s}}=\sqrt{\frac{1\cdot29}{1\cdot34}\cdot\frac{112}{1650}}=\frac{1}{3\cdot9}$$ so that the twine is 2½% too thick.

$$\frac{W_s}{W_{ST}}=\frac{R}{R_s}\cdot\frac{1}{S^2}=\frac{112}{1650}\cdot\frac{16}{1}=1\cdot08$$ so that the twine is 8% too heavy.

The estimated weight of model from original

$$=\frac{217}{64}\times1\cdot08+\frac{106}{64}=3\cdot66\text{ lb (netting)}+1\cdot7\text{ lb (ropes)}=5\cdot36\text{ lb.}$$

The actual weight of the model was 3·4 lb (netting) + 1·1 lb (ropes) = 4·5 lb

hese comparisons are good because, though the model turns out to be 12% lighter than it should be calculated from the original, the difference between one original and another may vary as much as is in any case, as the figures already quoted from the two netmakers show.

It does not in this case matter how the flotation of the model is calculated; the answer is the same in ny case as indeed it should be. The simplest way is to scale down the flotation from the original 220/64 lb 11×5 oz floats and since this flotation turned out to be satisfactory in practice the status of the true odel is to that extent established without compromise.

The weighting of the 4 lb groundrope with only 3½ lb of chain gave a satisfactory model performance here again compromise is avoided with the true scale model.

It is instructive to return to the *eighth-scale model* of the 30 ft net for a moment, just to see how the nits of accuracy deteriorate with this change of scale. Allowance must be made for the fact that, when is model was made, these modelling rules had not been worked out in detail, so that now no doubt a etter model could be made, but not all that much better.

The model was made with the square and batings in 1 in. mesh, so that $S_m=\frac{1}{3\cdot5}$. The twine used was 2/9s, 1960 yards/lb.

$$S_d=\sqrt{\frac{1\cdot29}{1\cdot34}\cdot\frac{112}{1960}}=\frac{1}{4\cdot27}$$ so that the twine is 22% too thin.

$$\frac{W_s}{W_{ST}}=\frac{R}{R_s}\cdot\frac{1}{SS_m}=\frac{112}{1960}\cdot\frac{8\times3\cdot5}{1}=1\cdot6$$ times too heavy.

The estimated weight of the model from the original is

$$\frac{217}{8^3}\times1\cdot6+\frac{106}{8^3}=0\cdot68\text{ lb (netting)}+0\cdot21\text{ lb (ropes)}=0\cdot89\text{ lb}$$

whereas the actual weight of the model = 1·48 lb, not very good agreement.

In this case the ropes of the model were also of cotton so its underwater weight would be 1·48 (1·34—1) ·1·34 = 0·38 lb.

For this model the required flotation should be

0·19 lb (weight of upper half of model underwater) + $\frac{184}{8^3}$ (scale upthrust) = 0·19 + 0·36 = 0·55 lb.

The upthrust of one resin-covered ping pong ball was $5{\cdot}32 \times 10^{-2}$ lb $\therefore$ number of floats required =

Twelve such floats gave this model quite a comparable performance both with the original and w the quarter-scale models, except for its drag which was rather indeterminate. Thus in spite of rather lar discrepancies in weight compared with what it ought to have been, the performance was affected l than might have been supposed.

It would be rather tedious to follow through the same details for the models of the Granton tra the large Aberdeen trawl as used by F.R.S. "Explorer" and the small otter trawl used by F.R.V. "Mar In dealing with three models of a single trawl the aim has been to show by three examples:

1. The compromises necessary to achieve correct performance in a quarter-scale model wh meshes and twine diameter are reduced by less than the model scale.
2. The lack of compromise necessary when a true quarter-scale model is used.
3. The deteriorating accuracy of model making when an eighth-scale is used.

IMPROVING THE SHAPE OF NETS

The four nets discussed in this section, the wing trawl, the 30 ft Aberdeen net, the 48 ft Aberdeen and the Granton net, are all now in common use.

How a Bad Net was Turned into a Good One (Plates 4 to 9 and Figs. 9 to 14)

When the idea of trawling from a 75 ft M.F.V. was first mooted five or six years ago it was particula herring trawling that was under consideration. The only specification for a suitable net we then had w that shown in Fig. 9. A full-size and a three-quarter size version of this net were made and used fr time to time on one or another of the research vessels. However, these nets never proved really satisfact for herring catching. The greatest headline height ever attained with the bigger net was 12 ft, indifferent height for herring trawling, although it seemed fairly good at the time. Some underwa observations made on the smaller version indicated that its shape was not satisfactory.

An eighth-scale model of the net (Fig. 10) was made but the model proved even less satisfactory th the net. This is a typical example in which making an eighth-scale net is not easy. The mesh of the origi is small, it changes frequently and the twine is of cotton, so that when it comes to making the model ou such sheet netting as is available in the thinnest cotton twine, an exact replica with all these changes mesh size is almost impossible. The thinnest cotton twine is still far heavier than it should be for suc model and as a result otterboards bigger than to scale were necessary to spread the model prope These snags are recounted because they would not be met if the model were made at quarter-scale w a half-scale mesh and twine size. The shape of the model in operation was satisfactory enough from belly to the codend but there were three major defects in the shaping of the forward part of it:

1. There was a big bulge in the selvedge at the join of the top wings and square. The selvedge in region of the bulge sagged towards the ground.
2. The lower wings, for all their considerable width, were not giving the net the height that it sho have had.
3. There was too much slack in both the upper and lower wings. This caused folds to appear the wings themselves and the square of the net to become unnecessarily distorted.

The reason for the first fault was that there was not enough width of netting lint at the top of square to match the width of lint at the base of the top wings. The square was moreover bated far rapidly. The shape was much improved by modifying the model as shown in Fig. 11. The top wi were tapered at the outside rear edge. A change of mesh size was introduced into the square and selvedges bated less rapidly.

The second fault is a more interesting one because its solution has, in recent years, been a departure in net design. The wide lower wings were intended to give height to the net but the th

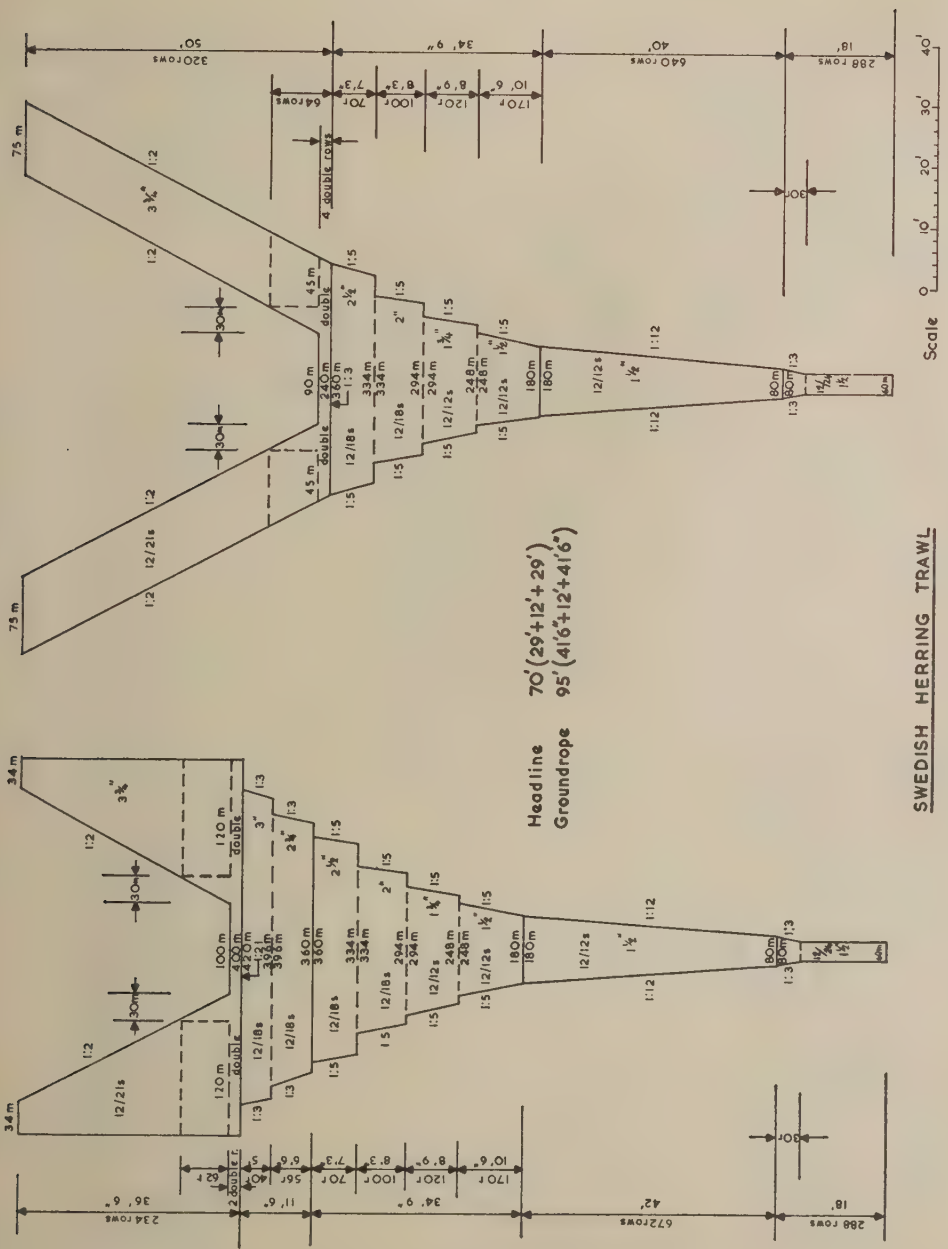
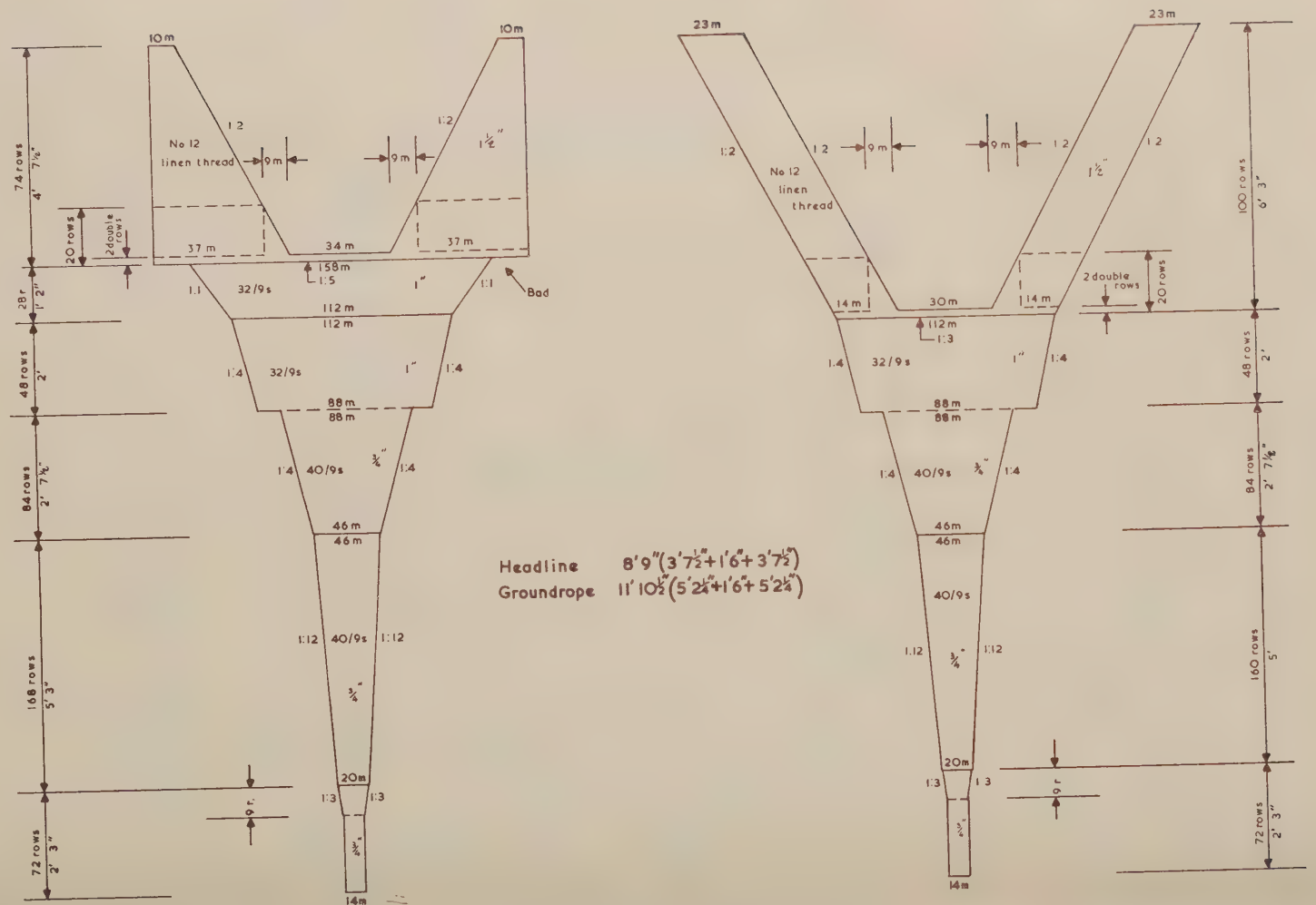

SWEDISH HERRING TRAWL
Headline 70'(29'+12'+29')
Groundrope 95'(41'6"+12'+41'6")
Scale
0 10' 20' 30' 40'
75 m
34 m
320 rows
640 rows
288 rows
4 double rows
2 double rows
double
30r
45 m
90 m
100 m
120 m
180m
240 m
248 m
294m
334 m
360 m
400 m
442m
12/21s
12/18s
12/12s
1:2
1:3
1:5
1:12
3¼"
3"
2¾"
2½"
2"
1¾"
1½"
1¼"

Fig. 9

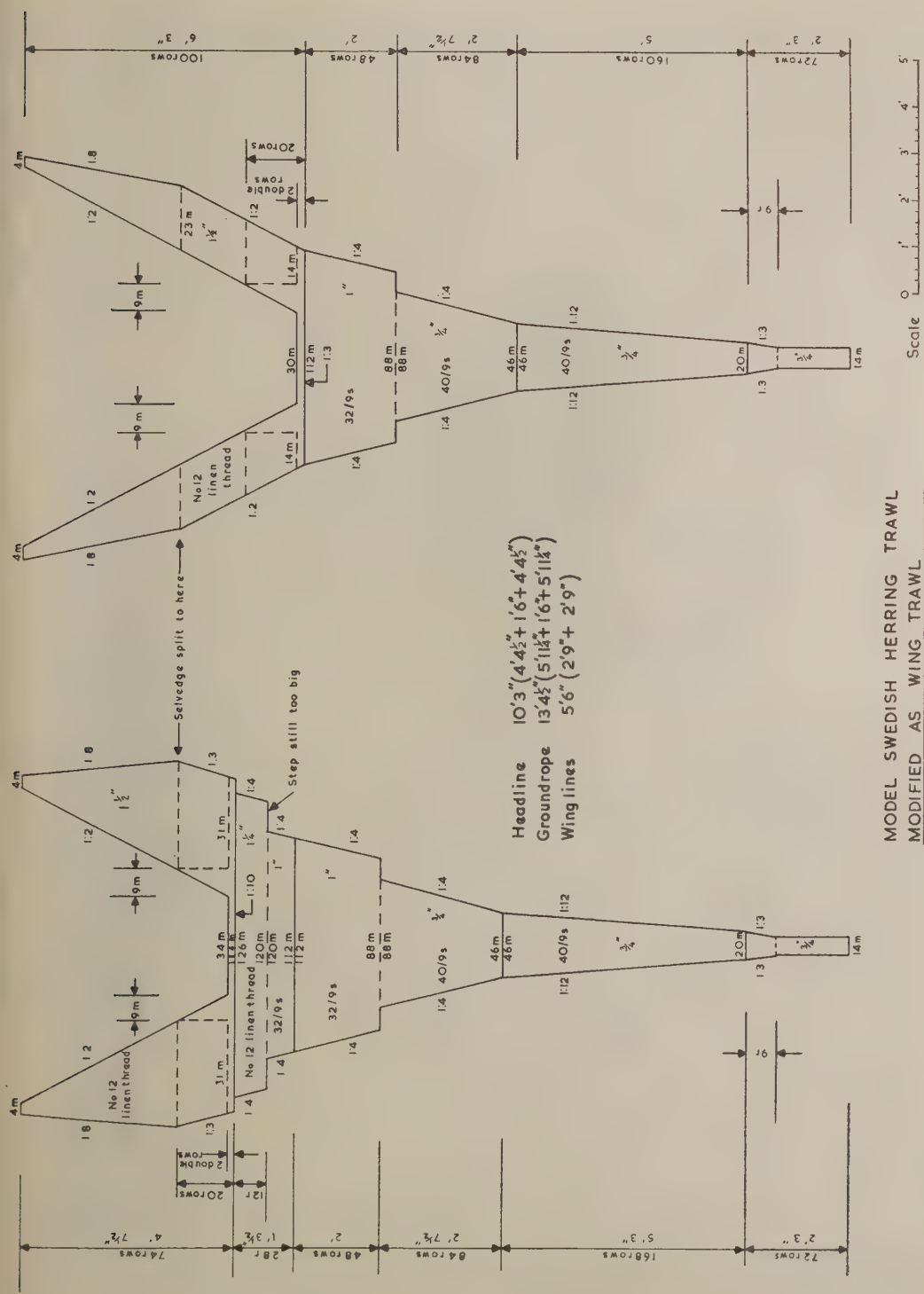


Headline 8'9"(3'7½"+1'6"+3'7½")
Groundrope 11'10½"(5'2¼"+1'6"+5'2¼")

MODEL SWEDISH HERRING TRAWL

Scale 0 1' 2' 3' 4' 5'

Fig. 10


Selvedge split to here
Step still too big
No 12 linen thread
Headline 10'3"(4'4½"+1'6"+4'4½")
Groundrope 13'4½"(5'1¼"+1'6"+5'1¼")
Wing lines 5'6" (2'9"+ 2'9")
Scale 0 1' 2' 3' 4' 5'

MODEL SWEDISH HERRING TRAWL
MODIFIED AS WING TRAWL

Fig. 11

of the water on the wing end caused the wing end retaining rope to bow; and the longer this rope w made, in order to increase headline height, the worse became the bow in it. Like the action on a tube toothpaste when one end is squeezed, the bow at the fore end passed progressively down the wing, form a flabby bulge at the join of the lower wings and belly, below the square. Cause and effect are se in Plates 4 and 5. Shortly after these early experiments the Fishery Officer in Aberdeen volunteered t information that the Swedes had started using bottom herring trawls in which the wing ends were fork like the fangs of a snake. This seemed a good remedy for the defect encountered with the model so it w modified along these lines. This style of trawl has come to be known as the Vinge or wing trawl (Fig. 1

The last of the three defects (Plate 6) was simply remedied by lengthening the headline and footro but a little explanation of why too much lengthways slack in the top wings does cause distortion of t square might be worth-while. The inside edges of the wings are constrained by their setting to the headli while the outside selvedges are not, and therefore hang farther back than the inside edges. The sha of top wings and square, instead of being as shown by the continuous line of Fig. 12, becomes as shown

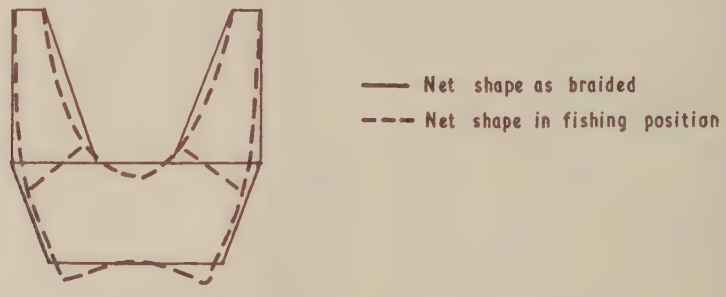


Fig. 12. Swedish Herring Trawl.

the dotted line. Setting the top wings fairly tightly on to the headline helps to overcome this distortion a if the net is made in nylon, as some wing trawls are, the fly meshes of the top wings are best set on the headline length for length with no slack at all.

Three views of the net as finally modified are given in Plates 7, 8 and 9. The shape of the mo is now satisfactory in every way except, perhaps, that the step in the middle of the square might be ma less pronounced, for instance by making the net wider at the top of the batings, the belly and at the b of the lower wings.

Based on the lessons learned from this model and also on those learned in herring trawling, wi trawls have been made for two research vessels, one for F.R.V. "Clupea" and one for the more power "Mara". The specifications of these nets are given in Figs. 13 and 14. Both can be regarded as prov nets for these ships.

A Detailed Discussion of the Aberdeen 30 ft Trawl (Plates 10 to 14 and Figs. 15 to 19)

The Aberdeen trawl (Fig. 15) is what might be described as a hard-ground trawl, a trawl in which, order to restrict the amount of damage sustained, its length in proportion to its width is compressed; trawl like an angler fish with a big bite for the size of its belly, a greedy trawl. In attempting to modify a improve it, its function as a hard-ground trawl should be borne in mind and no change made to its chara teristic features, short wings, short and rapidly tapered belly and batings. Within these limits there is s room for quite a lot of improvement.

There should be no pockets or bulges of unnecessary netting as these surely do nothing to increase t fishing efficiency and only mean increased drag in the water and extra cost to make. As a general princi it may be stated that once the fish have moved far enough into the net to be seeking a way out, t

Plate 1 Motor coble and divers' dinghy.

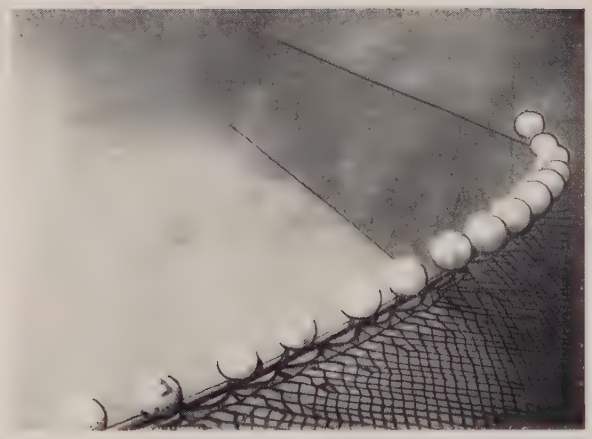


Plate 2 Forward wing and part of the square of the small Aberdeen 30 ft trawl. Shot from the film "Trawls in Action" made by "Basic Films" for M.A.F.F. Fisheries Laboratory, Lowestoft, in conjunction with Siebe Gorman Ltd.

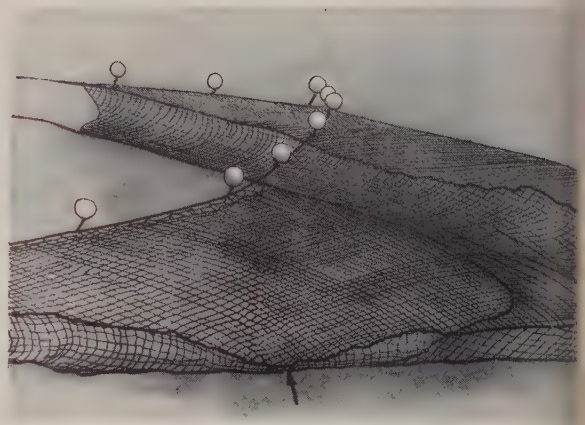


Plate 3 Eighth scale model of Aberdeen 30 ft net. Note the bulge in the selvedge.

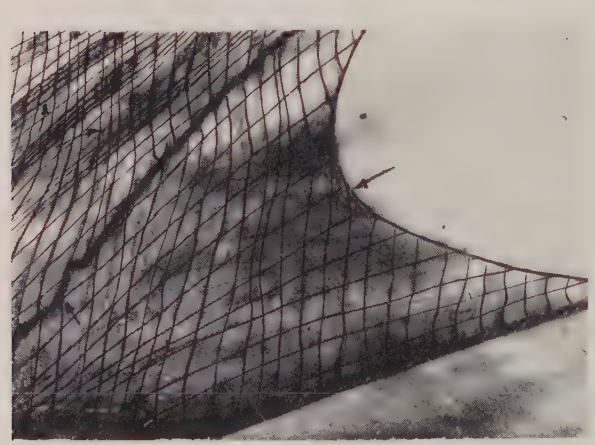


Plate 4 Model Swedish herring trawl. Note the bow in the wing end retaining rope. Note how the selvedge droops towards the ground and see the folds in the top wings caused by too short a headline.

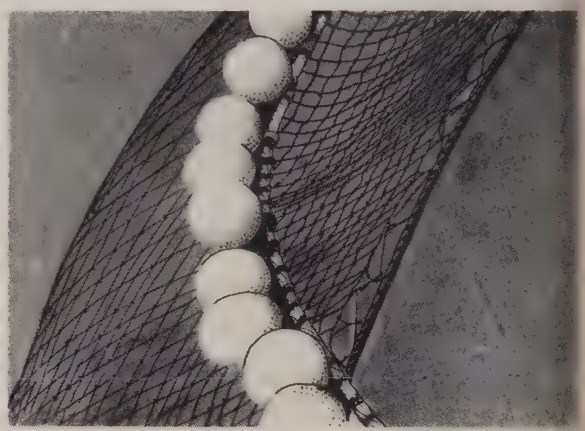


Plate 5 Model Swedish herring trawl. See how slack accumulates at the rear end of the lower wing. This is the result of the bad shape at the wing end as seen in Plate 4.

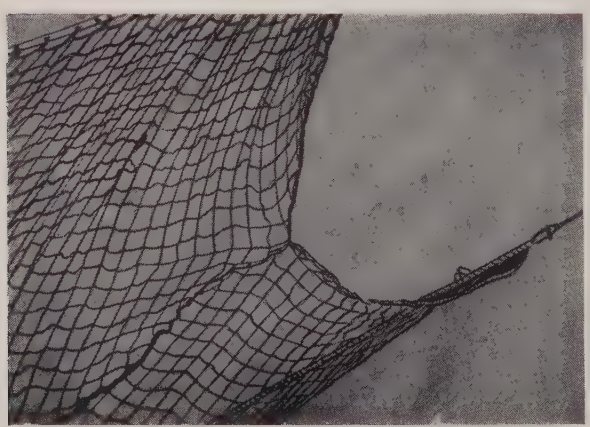


Plate 6 Swedish herring trawl. Effect of too much slack in the top wings.

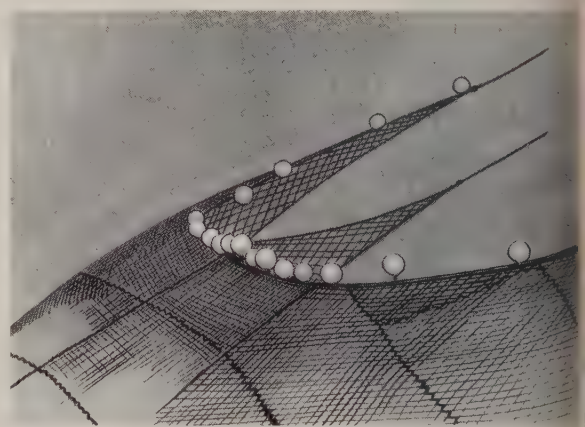
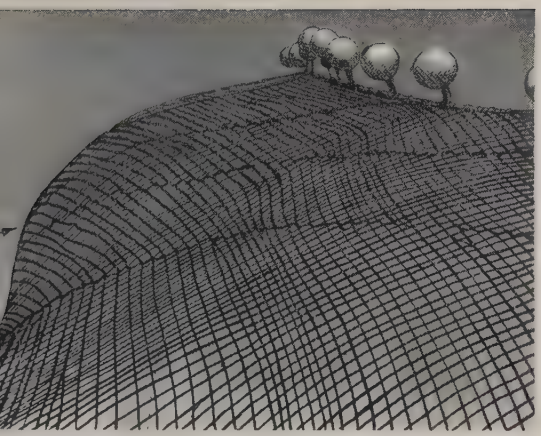


Plate 7 Model Wing Trawl as finally modified.



e 8 Model Wing Trawl as finally modified. Note the slight
e in the square as caused by the step shown in Fig. 11.

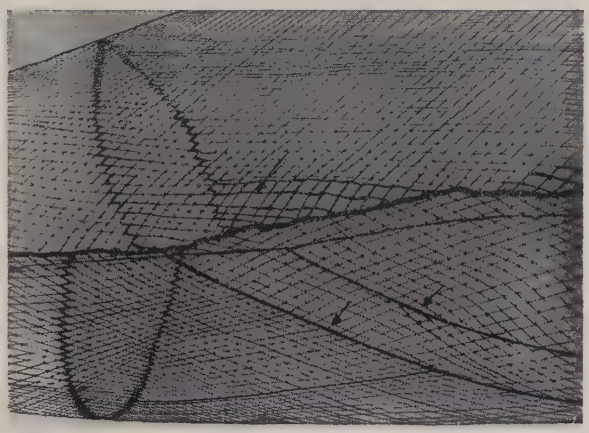
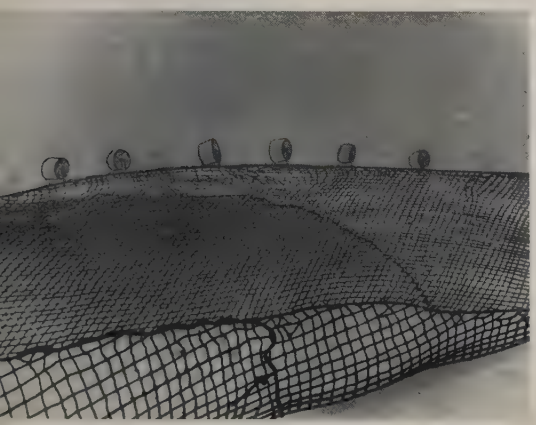


Plate 9 Model Wing Trawl as finally modified. The belly lines are seen here as they ought to be. Note the mending in the batings.

10 Model 30 ft Trawl. Tension in the square behind the
ter mesh is apparent. Setting in of the square along the headline
n is too tight. Note how the strengthening gusset in the top
has little apparent function.

Plate 11 Model 30 ft Trawl. Bulge on the selvedge at the join of the top wings and square. See also for comparison Fig. 16 and Plate 3.



12 Model 30 ft Trawl. Note the belly line rising almost
ally and how wide open the large meshes of the belly are
pared with those of the batings. Note how the selvedge sags
rds the top end of the square.

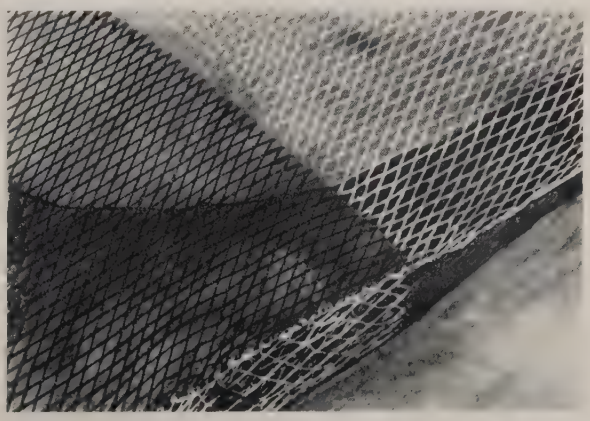


Plate 13 Model 30 ft Trawl. Groundrope seen through the square and batings. Note the elongation of the belly meshes behind the quarter mesh at the end of the bosom.

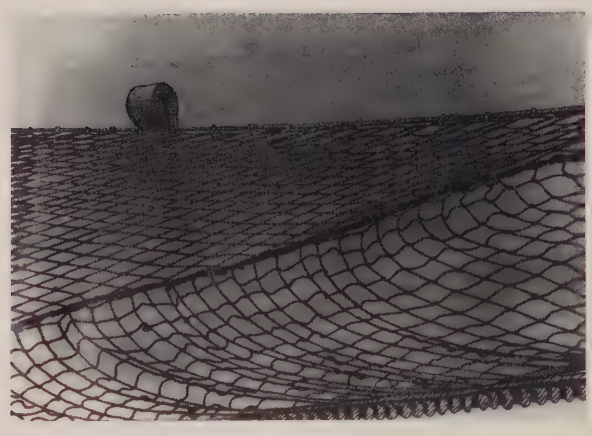


Plate 14 Model 30 ft Trawl showing much slack in the lower wing.

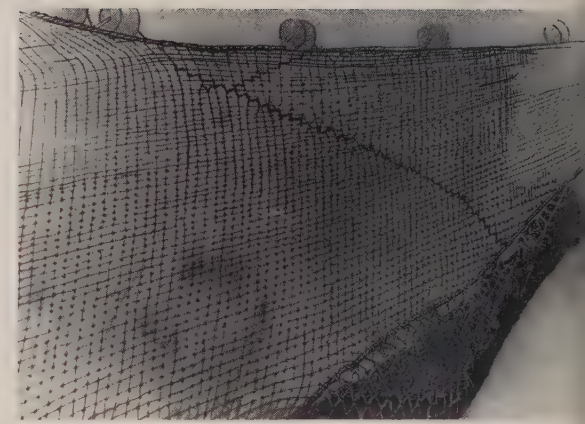


Plate 15 Model 48 ft Trawl, showing the generally good shap of the square and top wings but a slight tendency for th selvedge to bulge where they join owing to insufficient latera width at the top of the square (see Fig. 21).

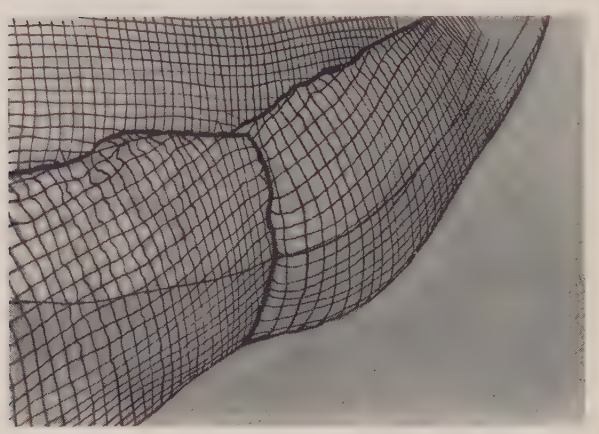


Plate 16 Model 48 ft Trawl. The belly extends over into the roof of the net owing to the top of the batings having less width than the top of the belly and also to the lenghthways slack set into the belly. Note how the belly line pinches the net.

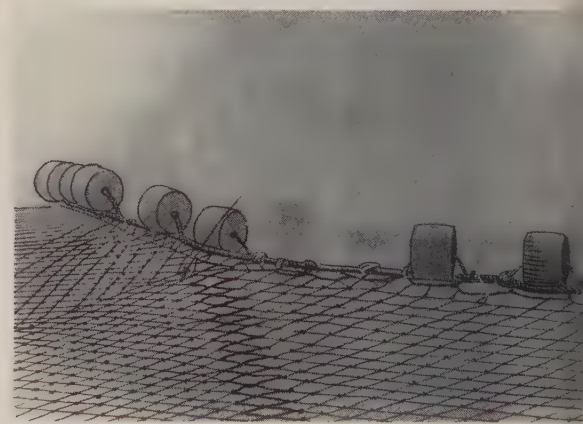


Plate 17 Model 48 ft Trawl. Tension is again apparent behin the quarter while there is no undue tension on the strengthenin gusset of the top wing.

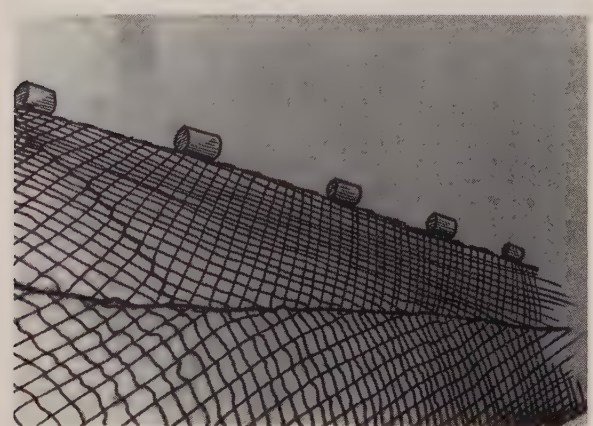


Plate 18 Model Granton Trawl showing the good shape of the lower wings, top wings and selvedge joining them. There is less slack in the lower wings than in the Aberdeen nets.

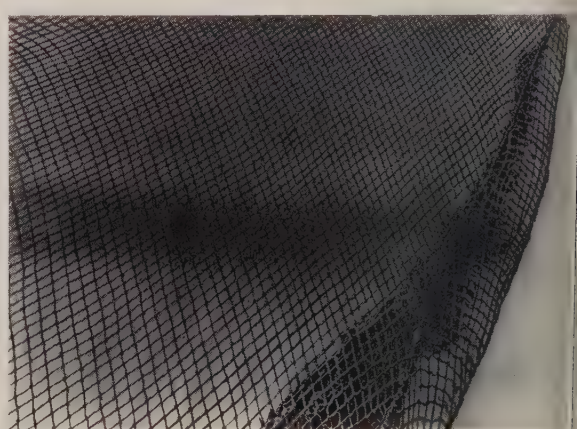


Plate 19 Model Granton Trawl. The great expanse of the squa is seen here. This net has a very large overhang.

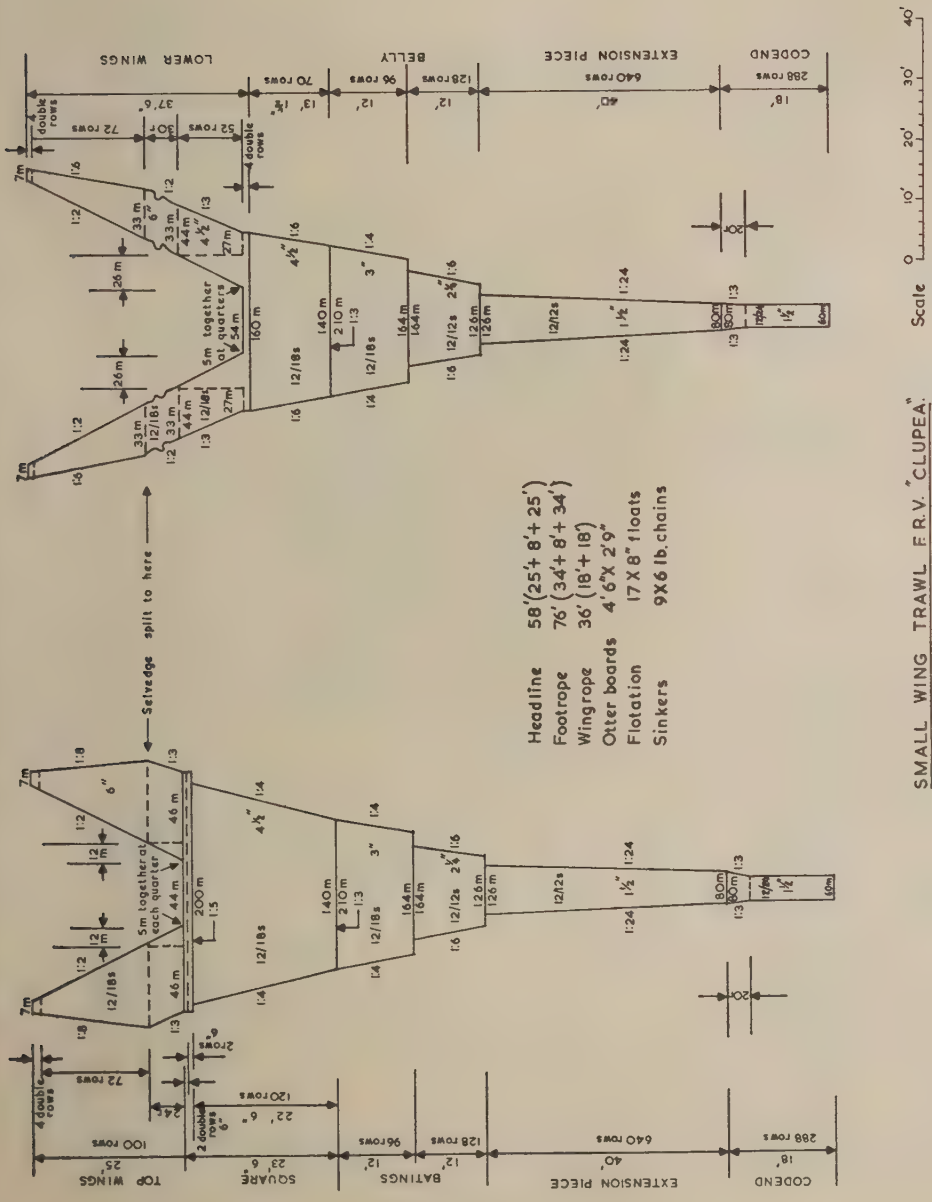

Selvedge split to here
Headline 58'(25'+8'+25')
Footrope 76'(34'+8'+34')
Wing rope 36'(18'+18')
Otter boards 4'6"X 2'9"
Flotation 17 X 8" floats
Sinkers 9X6 lb. chains
SMALL WING TRAWL F.R.V. "CLUPEA".
Scale
0 10' 20' 30' 40'
TOP WINGS
SQUARE
BATINGS
EXTENSION PIECE
CODEND
LOWER WINGS
BELLY
EXTENSION PIECE
CODEND

Fig. 13

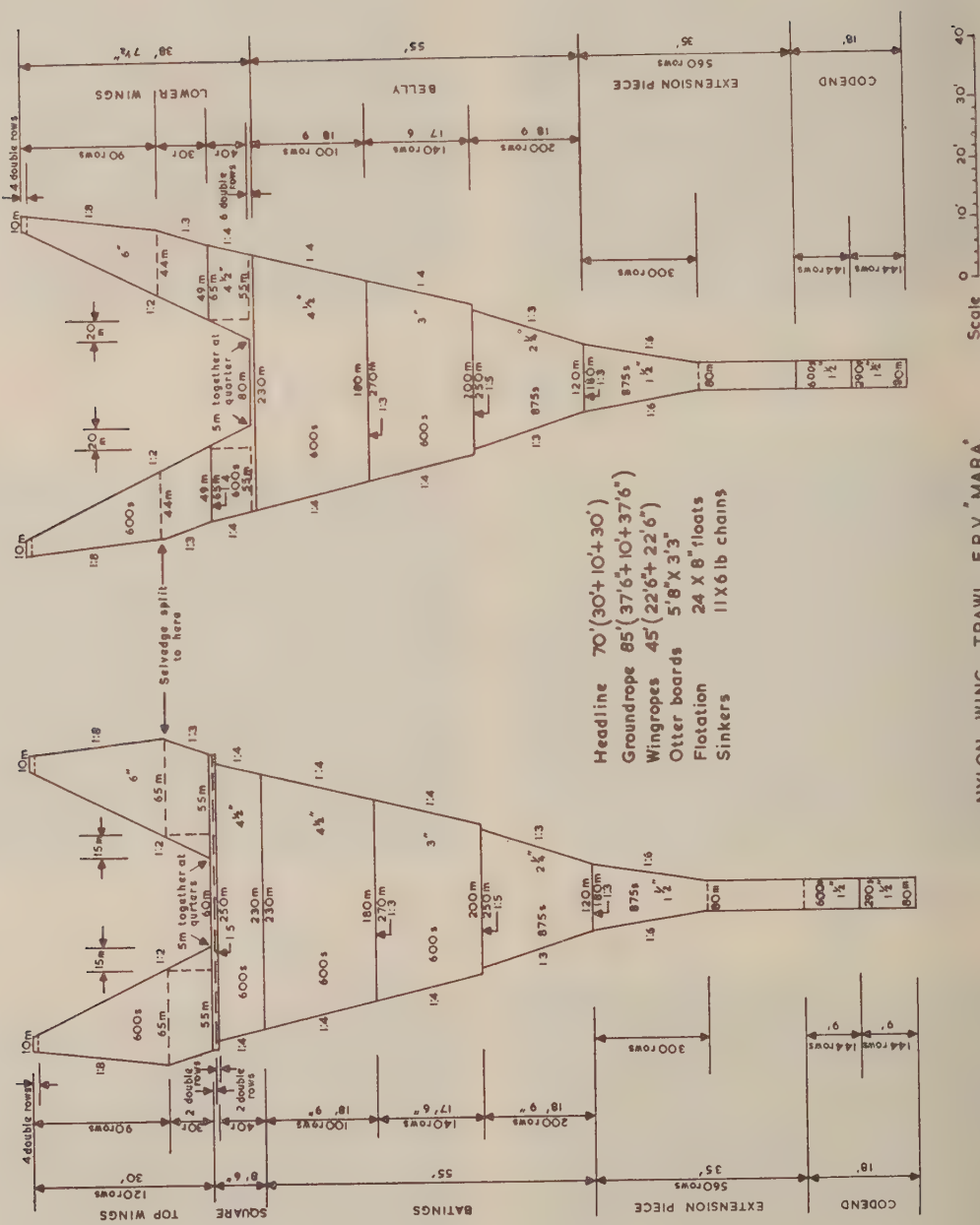

NYLON WING TRAWL F.R.V. 'MARA'
Headline 70'(30'+10'+30')
Groundrope 85'(37'6"+10'+37'6")
Wingropes 45'(22'6"+22'6")
Otter boards 5'8"X3'3"
Flotation 24 X 8" floats
Sinkers 11X6 lb chains
Scale
Salvage split to here
TOP WINGS
SQUARE
BATINGS
EXTENSION PIECE
CODEND
LOWER WINGS
BELLY
EXTENSION PIECE
CODEND

Fig. 14

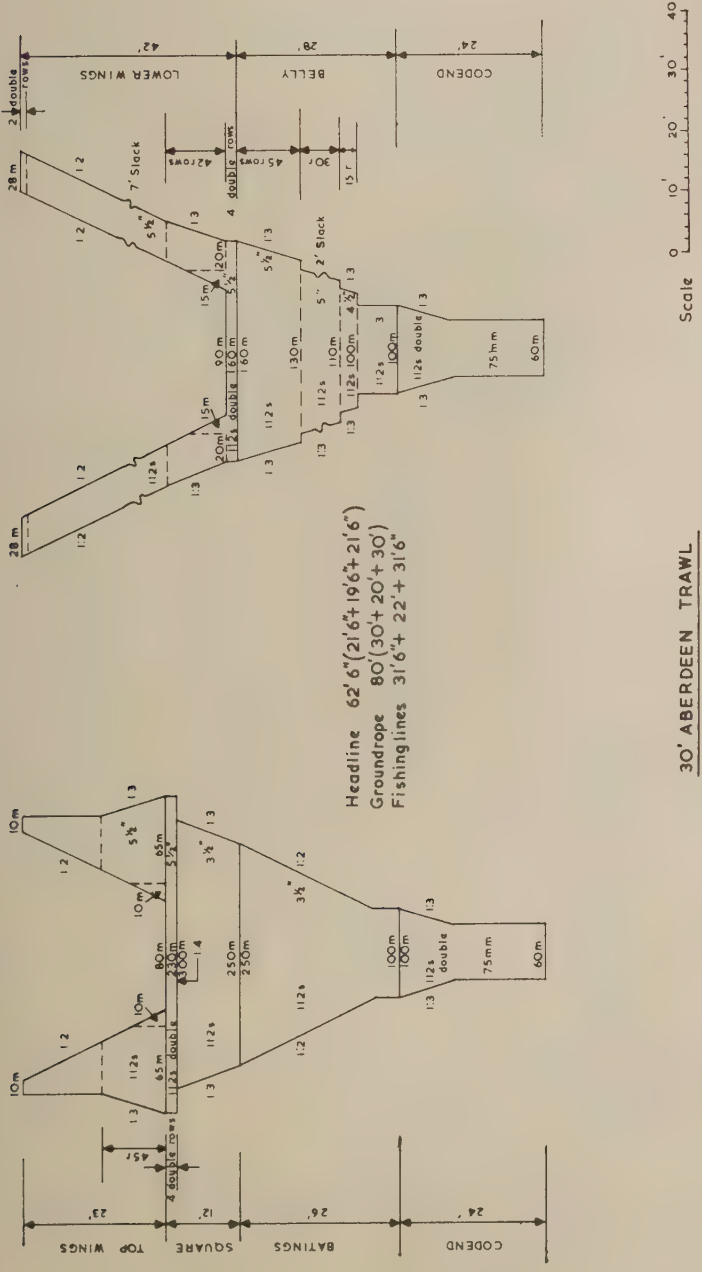

LOWER WINGS
BELLY
CODEND
2 double rows
42'
28'
24'
7' Slack
2' Slack
42 rows
45 rows
4 double rows
15 r
28 m
1:2
1:3
5½"
5¼"
5"
4½"
15m
20m
90m
160m
130m
110m
100m
112s
112s double
75mm
60m
Headline 62'6"(21'6"+19'6"+21'6")
Groundrope 80'(30'+20'+30')
Fishinglines 31'6"+ 22'+ 31'6"
30' ABERDEEN TRAWL
Scale
0
10'
20'
30'
40'
TOP WINGS
SQUARE
BATINGS
CODEND
23'
12'
26'
24'
4 double rows
45'
10m
65m
80m
230m
1.4
250m
3½"
3¼"
112s
112s double
100m
75mm
60m

Fig. 15

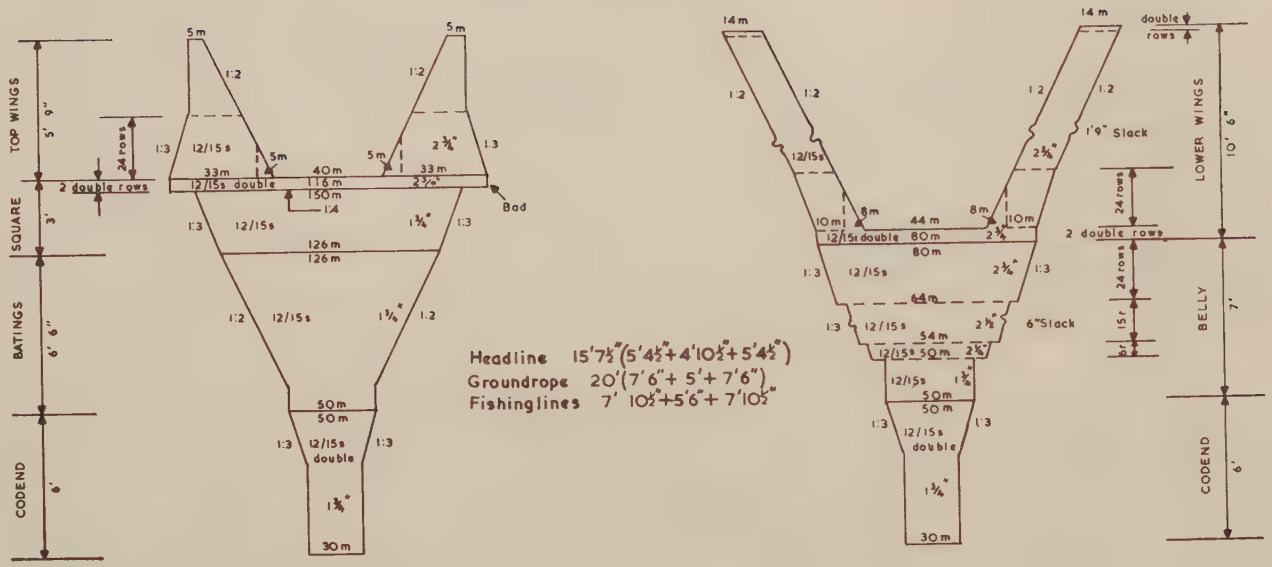

TOP WINGS
5' 9"
24 rows
2 double rows
SQUARE
3'
BATINGS
6' 6"
CODEND
6'
5m
1:2
1:3
12/15s
33m
40m
116m
150m
1:4
12/15s double
2⅜"
Bad
12/15s
1¾"
126m
126m
12/15s
50m
50m
12/15s double
30m
Headline 15'7½"(5'4½"+4'10½"+5'4½")
Groundrope 20'(7'6"+ 5'+ 7'6")
Fishinglines 7' 10½"+5'6"+ 7'10½"
14m
1:2
12/15s
10m
8m
44m
80m
12/15s double
2⅜"
1:3
12/15s
44m
54m
12/15s 50m
6"Slack
12/15s
1¾"
50m
50m
12/15s double
30m
double rows
1'9" Slack
LOWER WINGS
10' 6"
24 rows
2 double rows
24 rows
15r
BELLY
7'
CODEND
6'
MODEL 30' ABERDEEN TRAWL
Scale 0 2' 4' 6' 8' 10'

Fig. 16

sibility of escape should be precluded or, in other words, in the areas of net from which escape is sought mesh size should be sufficiently small to retain the marketable sizes. In a rapidly tapering net it is ely that escape is sought nearer the mouth of the net than would otherwise be the case and, therefore, t the large mesh should not be carried so far back into the net. On the other hand the more of the net t is in large mesh the less its drag and therefore for capturing large fish the large mesh net should be perior. The choice of mesh size in the regions of the net from which escapes are sought is thus rationally termined not by the minimum landing sizes alone but also by the relative abundance of larger fish. e relative scarcity of such larger fish in the North Sea was probably the underlying reason for the roduction in the 1930s of the small-mesh square and batings. Parts of the belly must be kept in large sh to allow as much bottom rubbish as possible to drop through it, since the more of this rubbish that sses into the codend the worse the chafing there will become. Experiments to determine the difference selectivity of the net with its forward part made in large mesh and in small mesh are planned, but in meantime it will be presumed that regions of the net from which marketable fish are likely to escape ould be made in mesh small enough to prevent escape.

The defects which are discussed here are those which are observed on models of the net, made at th eighth and quarter scales (Fig. 16). The defects in design as they appear from the above observations six in number:

1. Undue tension immediately behind the quarter meshes and distortion of the fishing square.
2. Shape of the top wings.
3. Shape assumed by the belly lines.
4. Shape assumed by the belly itself.
5. Length of groundrope.
6. Amount of slack in lower wings.

That there is undue tension behind the quarter meshes is seen in Plate 10, where the meshes are pulled o elongated diamonds. It can be seen that the part of the top wing which is strengthened next the arter is not the part in greatest need of strengthening. There are several methods of strengthening square immediately behind the quarter. Some of the distortion in the square could be avoided by aping the square so that the bating meshes in it run backwards from the quarters instead of along the ge, or the top wings could be shaped as they are in the Granton trawl (p.36), with extra batings in the engthening gusset so that the shape of the netting would more closely follow the shape that the headline umes. Alternatively a gusset might be let into the square behind the quarter. Perhaps simplest of all o take five bosom meshes together into the quartermesh. If this is done the headline bosom must also shortened as there are then fewer meshes to be spaced along it.

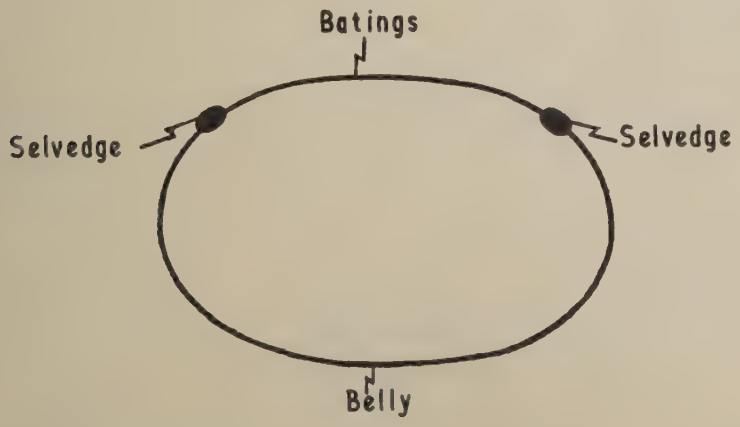


Fig. 17. Cross-section through the funnel of the net.

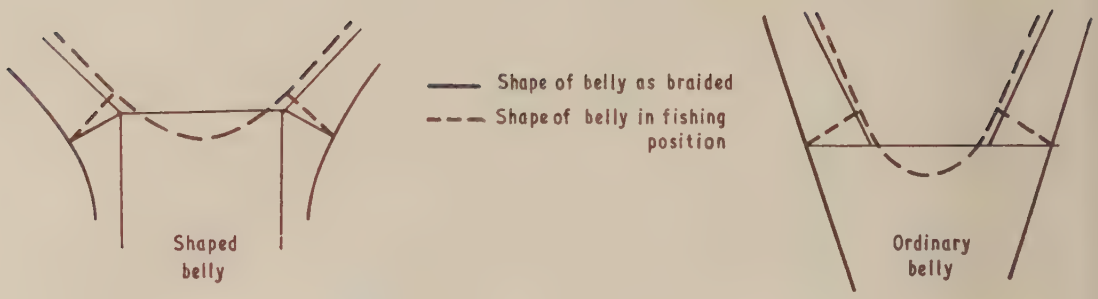
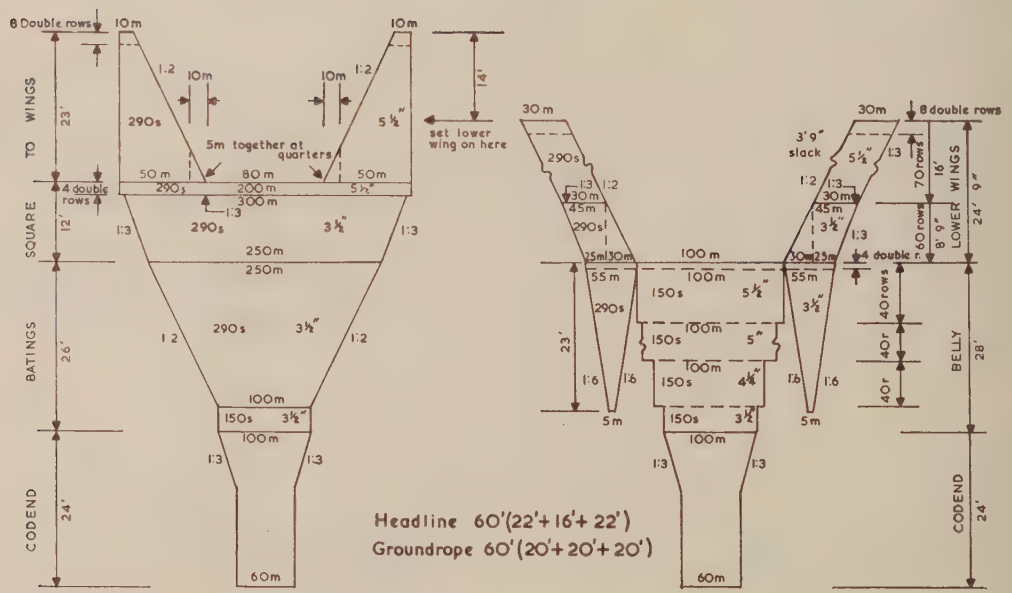


Fig. 18 Shaping the belly to avoid distortion.



NYLON TRAWL FOR 'SCOTIA'
REVISED SPECIFICATION OF 30' NET

Scale 0 10' 20' 30'

Fig. 19

In the top wings there are batings on the outside selvedge which do not appear to have any real ıction. They cause a bulge in the selvedge of the net where the top wings join the square. This bulge o be seen in Plate 11. There does not seem to be any good reason why the selvedge of the top wing ıuld not be straight with the wing 60 meshes across its base rather than 75 meshes. By doing this the lge in the selvedge is eliminated, twine is saved in manufacture, and the net is made simpler in pattern.

Looking at Plate 12, the shape assumed by the belly lines is hardly what is expected or desirable. ly line is almost a misnomer, indeed, for although it starts at the belly, it runs for most of its length the selvedge in the upper part of the net. A cross-section through the net appears as shown in Fig. 17. ally the selvedge should be only half way up, so that for a considerable part of its length the belly e, from where it leaves the selvedge, would be in the lower half of the net, protecting and strengthening s most important part. It may be stated at this point that the more the headline is raised to its maximum ıit by the addition of floats or patent lifting devices, the worse does the pinching of the belly by the ly line become. The reasons for the selvedge being so high are twofold. Firstly, it is attached at its ward end to the toe of the headline and therefore starts off high. Splitting the wing ends lowers the vedge and is a neater way of raising the headline height than by the brute force method of jacking up with more floats. The second reason is that, because slack is allowed in the lower net, the upper t carries more tension and the batings meshes become more elongated than the belly meshes which thus allowed a greater lateral spread. Put another way, the 28 ft belly being attached to the 26 ft tings is foreshortened by 2 ft and like a trestle gate when pushed in at the top it expands sideways. ıe reason for this 2 ft allowance of slack is not very clear but it does seem possible that the slackness the lower net serves as some protection from damage and in the meantime, until the necessity for it is ablished or rejected, it will be as well to retain it. It may be conjectured that the wide-open, large shes in the forward part of the belly are a probable region of escape for marketable-sized fish. In any se, either the escapes through this region are not significant, in which case the need for small-mesh uare and batings is not very convincing, or they are significant, in which case the sides of the belly ıuld be in small mesh also. Only a comparative fishing trial can settle that issue. Returning to the oblem of how to prevent escapes through the wide-open meshes at the sides of the belly, and how to tain a better shape for the belly lines so that they fulfil their intended function, a glance at Fig. 19 ll show how it could be done by running the belly lines from the ends of the bosom back along the vedge of the belly and side panels. Such a construction also has the advantage that the reduced belly, ıich stands the greatest chance of sustaining damage, can be made in heavier twine without making whole net much heavier.

It is questionable whether the groundrope from which the net derives its name is not too short at ft. The length of the top wing when roped out along the inside edge, plus the length of the square ng a 'halver' or diagonal line of knots comes to 33½ ft. The four double rows extending right across front of the belly account for nearly 1 ft, the bolsh line and fishing lines for perhaps another foot, ving 1½ ft unaccounted for. That the meshes behind the quarter-meshes on the footrope bosom are tremely elongated is to be seen in Plate 13. This is evidence of too short a groundrope pulling the bunts o far forward. The curve of the footrope makes it impossible to eliminate this defect altogether but, addition to lengthening the footrope, shaping the belly should also help as is indicated in Fig. 18. ı the left the fishing shape of the belly and the shape as braided are similar.

Finally, without questioning the need for slack in the lower wings, 7 ft of slack or 20% extra length the lower wings compared with top wings and square does seem an inordinate amount. The effect of is seen in Plate 14, and it is difficult to believe that something like 10% slack would not be enough.

From the foregoing discussion a revised specification for the small Aberdeen trawl has been drawn in Fig. 19 for a vessel of 300-350 b.h.p. Such a vessel uses smaller otterboards than usual so that in is specification the twine is scaled down in diameter to match the reduced shearing force of the boards; the use of nylon this is done without loss of strength. The lower wings are shortened for ease of handling.

Discussion of the Aberdeen 48 ft Net (Plates 15 to 17 and Figs. 20 and 21)

The large Aberdeen trawl is another net which attempts a large bite for the size of its belly. The ngs are long and deep, attempting not only a large spread but a large gape as well. Unless the trawler

is powerful enough to pull larger doors and so to spread these long wings effectively there does not s much to be gained by the use of this net rather than the smaller 30 ft trawl. Its other features are that square is short and both square and batings are in small mesh. In some ways it appears rather an congruous sort of net. Looking at the specification drawing (Fig. 20) one is tempted to ask: "If it is m as a hard-ground trawl why the long wings to sustain the damage? If it isn't, then isn't the rest of net on the neat side? Then, aren't the square and batings a bit on the neat side in any case so fa lateral breadth is concerned? All round doesn't it just try to bite off a little too much?" These quest are primarily the result of experience gained with models, although they may seem to be anticipati little. Having had the benefit of such experience, it is felt they are the sort of thing that can in futur gleaned from a scrutiny of the specification drawing alone, provided it is drawn up according to r This by no means implies that modelling can be dispensed with as modelling is at the moment virtu the only method by which these anticipations may be checked. The model tests are governed by anticipations.

As in the 30 ft net the batings form only the roof of the net while the belly forms both bottom sides. In this case, however, the effect is even more accentuated because the belly not only has m lengthways slack set into it than the batings but has more lateral slack as well. The result of this is to m the pinching of the net by the belly lines more acute. The step in the specification drawing at the joi square and top wings does lead to a slight but still appreciable bulge in the selvedge of the net when viewed under water. This, as seen in Plate 15, gives a fair indication of the limit permissible if and w it is necessary to introduce such a step into the design of a net.

There is therefore room for improvement in the design of the Aberdeen 48 ft net. Without mal any too drastic modifications the following are the lines along which such an attempt would be ma

1. Carry the taper in the outside edge of the top wings further towards the wing tip by reducin rapidity.
2. Split the wing ends to reduce the height of the selvedge.

2a. Alternatively, since the net has some of the features of a hard-ground trawl, accentuate thes truncating the lower wing and handling the gear German fashion (Dickson, 1958).

3. Reduce the amount of slack in the lower wings.
4. Introduce strengthening gussets in the square behind the quarter meshes.
5. Give more lateral slack at the top of the square to reduce or eliminate the step in the specifica drawing.
6. Make the width of the top of the batings as much as that of the top of the belly.
7. Possibly divide the belly into centre and two side pieces, as suggested for the 30 ft net, with side pieces in the same mesh size as the batings and run the belly lines down the selvedges join the centre belly to the side panels.

It does not necessarily follow that the making of such alterations to the design of the net wo increase its fishing potentialities. Any such increase could not in any case be quickly assessed since m would depend on the nature of the ground chosen for the assessment, the species and size range of fish being sought and, last but not least, just what the pattern of behaviour of these fish happened to at the time and place chosen for the trial, particularly in regard to their vertical distribution near the bed. Such a comparative fishing test between a standard and "improved" trawl is rather like a foot match. The score can be studied and the relative form of the competitors discussed but replays on diffe grounds and in different conditions can tell different stories. What is more certain is that, by reshap such a net, the tension in the netting can be more evenly distributed, giving all parts an equal st as fishermen say, and to that extent the net is strengthened. Moreover, this can as often be done, no inserting extra bits into the net but by cutting out unnecessary parts.

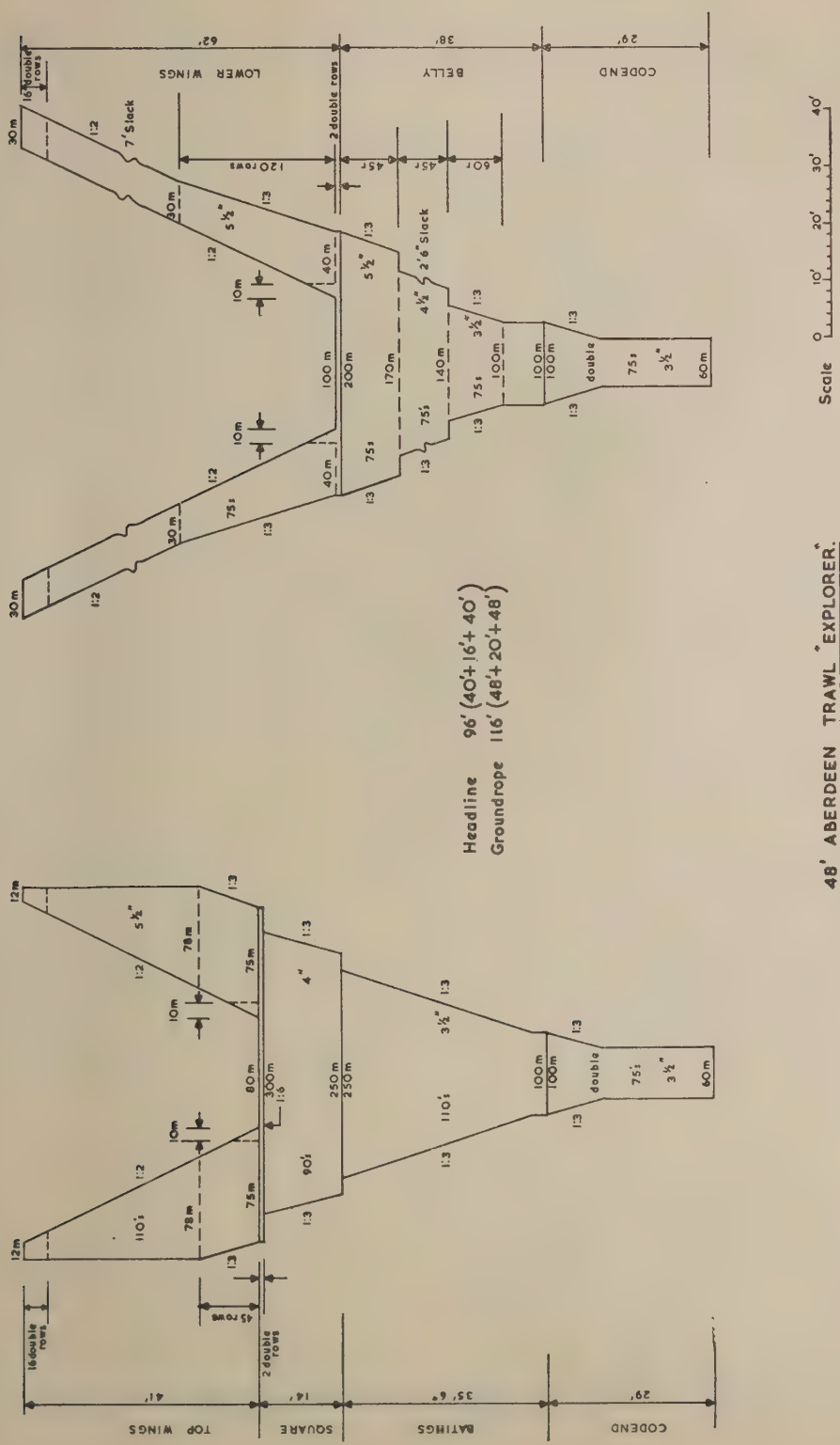
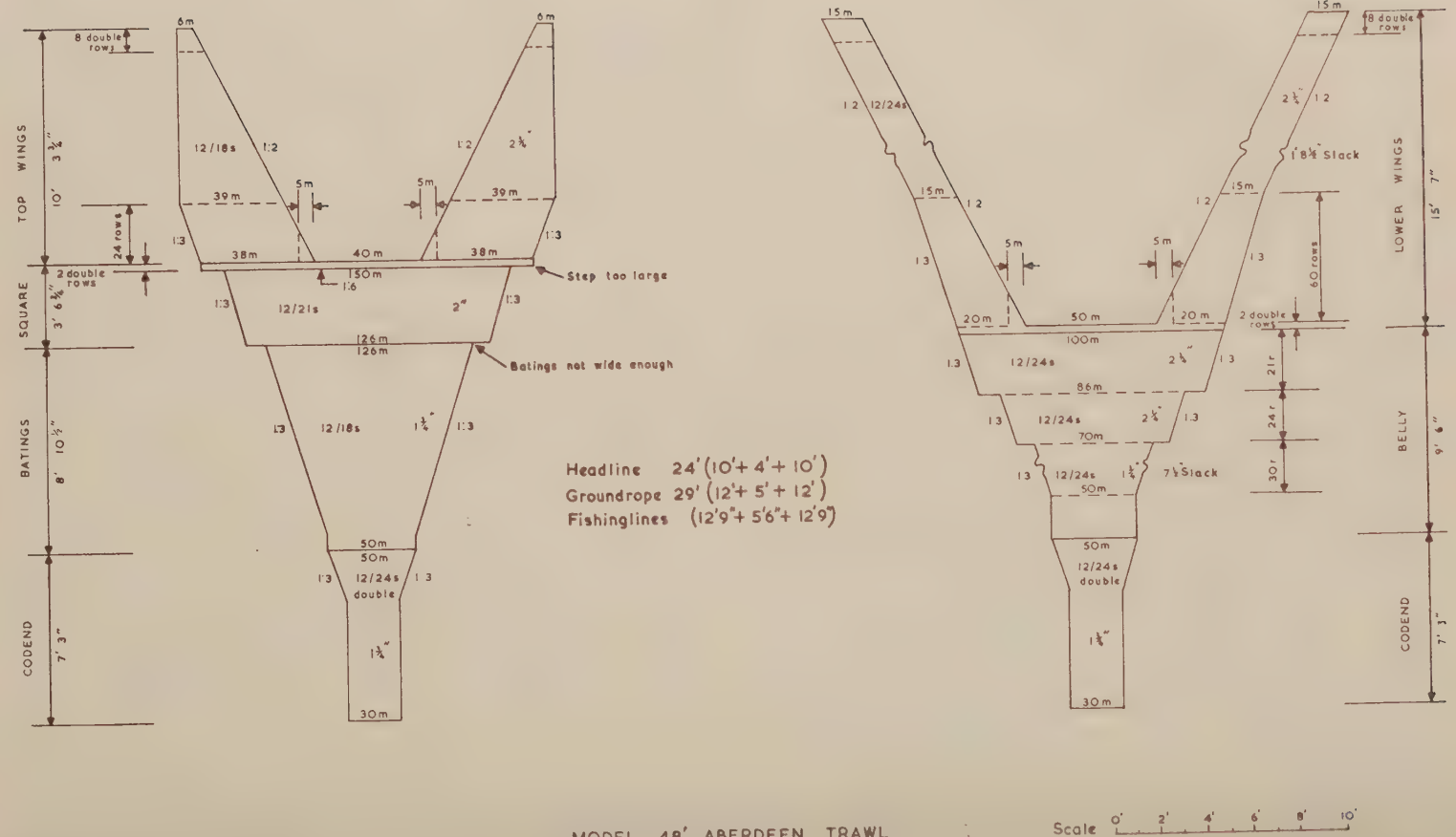

LOWER WINGS
BELLY
CODEND
62'
38'
29'
16 double rows
2 double rows
120 rows
45 rows
7' Slack
2'6" Slack
30m
40m
100 m
200m
170m
140m
75s
100m
60m
1:2
1:3
5½"
4½"
3¾"
3½"
4"
10m
double
Headline 96' (40'+16'+40')
Groundrope 116' (48'+20'+48')
Scale 0 10' 20' 30' 40'
48' ABERDEEN TRAWL "EXPLORER".
TOP WINGS
SQUARE
BATINGS
CODEND
41'
14'
35' 6"
29'
12m
78m
75m
80m
300m
1:6
250m
110s
90s
106s

Fig. 20



MODEL 48' ABERDEEN TRAWL

Fig. 21

Discussion of the Granton Trawl (Plates 18 and 19 and Figs. 22 to 24)

The specification drawing of the Granton net shows that its general features are rather different from ose of the Aberdeen nets. Its groundrope is much longer in proportion to the headline with a pro- rtionally larger square and shorter top wings in consequence. Indeed the very large square and over- ng are its most characteristic features. The other main difference is that the entire forward part of the is made in large mesh. The net is also more gradually tapered in the belly and lastly the lower wings rather shallow at the toe end.

The general shape of the fore part of the net requires no special comment. In particular, it was ticed that the shaping of the top wing strengthening gussets (see specification drawing, Fig. 22) caused s distortion of the square and less tension in the meshes immediately behind the quarter meshes than s the case with the other nets. This is because the shaping of these gussets makes the net more nearly proach its shape in the fishing position. A good part of the lower wing of the model is seen in Plate 18. ain the shape is satisfactory, particularly as there is not an undue amount of slack in it.

So long as the headline height of the model was less than 2 ft 3 in. (9 ft), the belly lines did not pinch net unduly but when flotation was added to bring the headline height up to 2 ft 9 in. (11 ft) then nching did occur. It may therefore be taken that, unless the net is modified in shape, somewhere about ft is the maximum headline height obtainable from the full-sized Granton trawl without its shape coming distorted.

There is little fault to find with the Granton net. There are no awkward pockets or bulges except nen the headline is raised too high. The longish belly with the more gradual taper lends the net a aceful appearance in the water. One wonders all the same why such a great overhang, double that of Aberdeen nets, has been chosen. The shortened headline in proportion to the groundrope must surely row greater tension on the shorter line and tend to ride it down and yet it is greater headline height at is continually being sought. The experiments described here certainly do not show that the way to hieve this is simply to add more floats, patent or otherwise. First of all the net must be made in a rm which will allow the headline to rise without distorting the net. This can be done by splitting net at the wing ends, so allowing the height of the selvedge to fall, which in turn allows more height the net before the belly line distorts its shape and also allows the headline to rise somewhat. The adline can also be lengthened by increasing the length of the top wings and reducing the length of e square by the same amount.

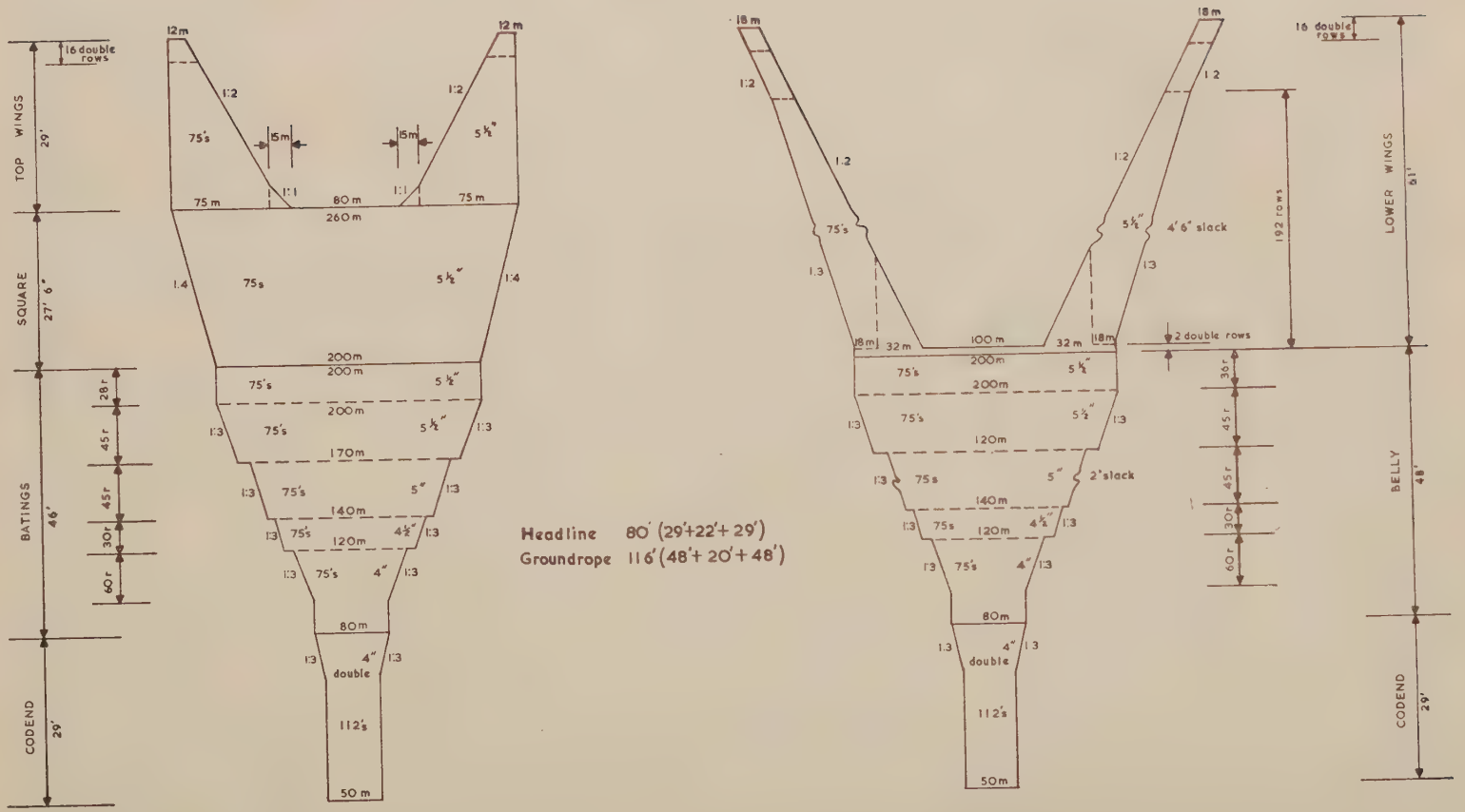
A revised specification was drawn up along these lines (see Fig. 24) and the model modified cordingly. Table IV is made up of operational dimensions measured on the models under water and ould not be taken as nullifying the old and general maxim that you cannot have your cloth in length d in breadth too. It is, for instance, quite possible to design and operate, even from large trawlers, ts with three times the headline height of the Granton trawl, but unless the taper of the net is made duly rapid it takes a good deal more netting to do it. The advantages of a greatly increased headline ight have then to be set against the disadvantages: (1) increased amount of netting to sustain damage, increased drag, and (3) reduced spread unless larger or better otterboards are used.

Table IV

Improving the operating dimensions of a net by cutting out parts of it

	Model Granton Net		Modified Model Granton Net	
	With	With	With	With
	18×5 oz floats	20×5 oz floats	18×5 oz floats	22×5 oz floats
eadline height	2ft 3in. (9ft)	2ft 9in. (11ft) net distorted	2ft 7½in. (10ft 6in.)	2ft 10in. (11ft 4in.) net not distorted
read between wing tips	10ft 6in. (42ft)	10ft 6in. (42ft)	11ft 6in. (46ft)	11ft 3in. (45ft)

It shows that *within limits* it is possible to improve both the gape and spread of a net by cutting away rts of it.



GRANTON TRAWL

Fig. 22

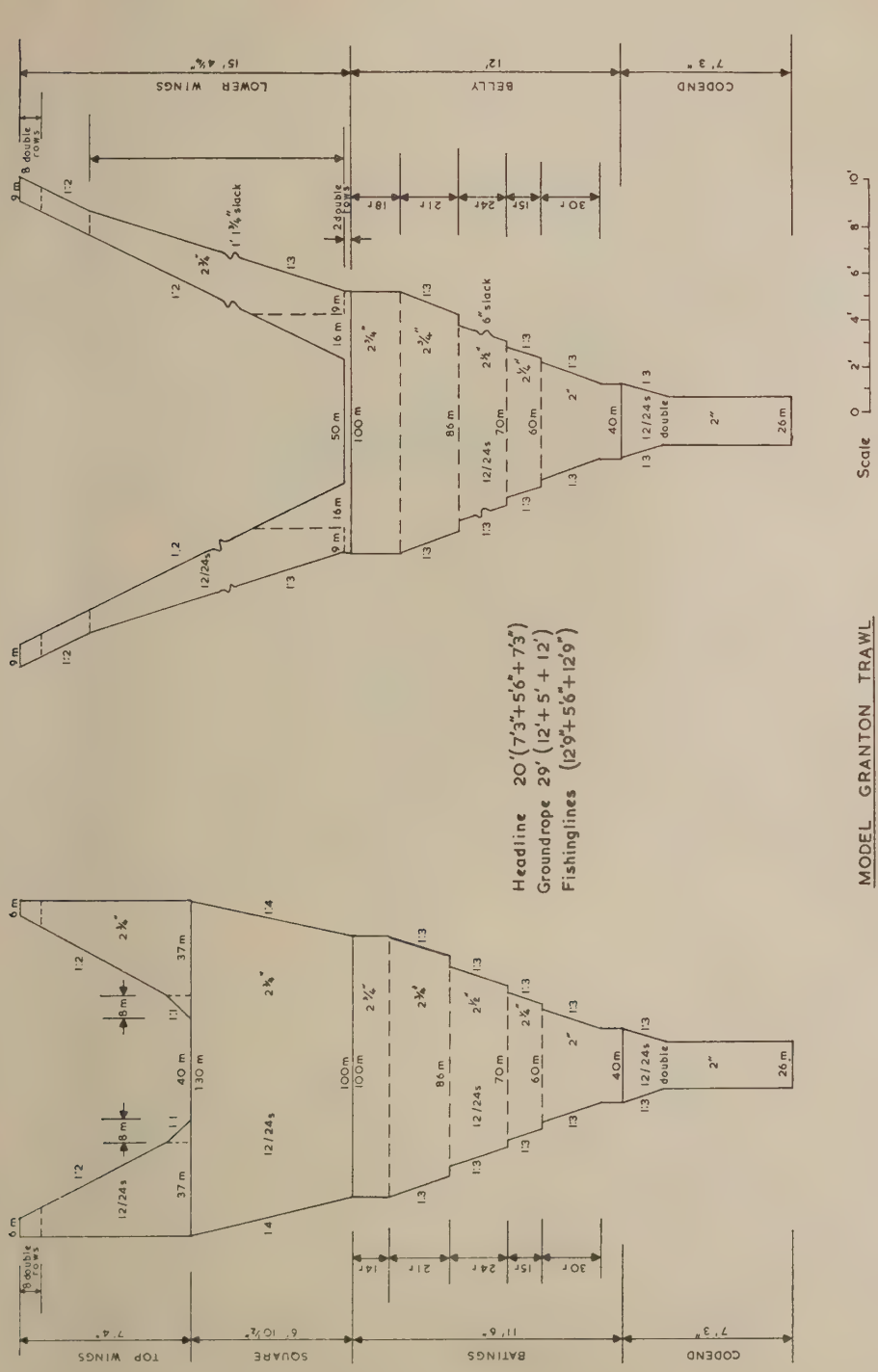
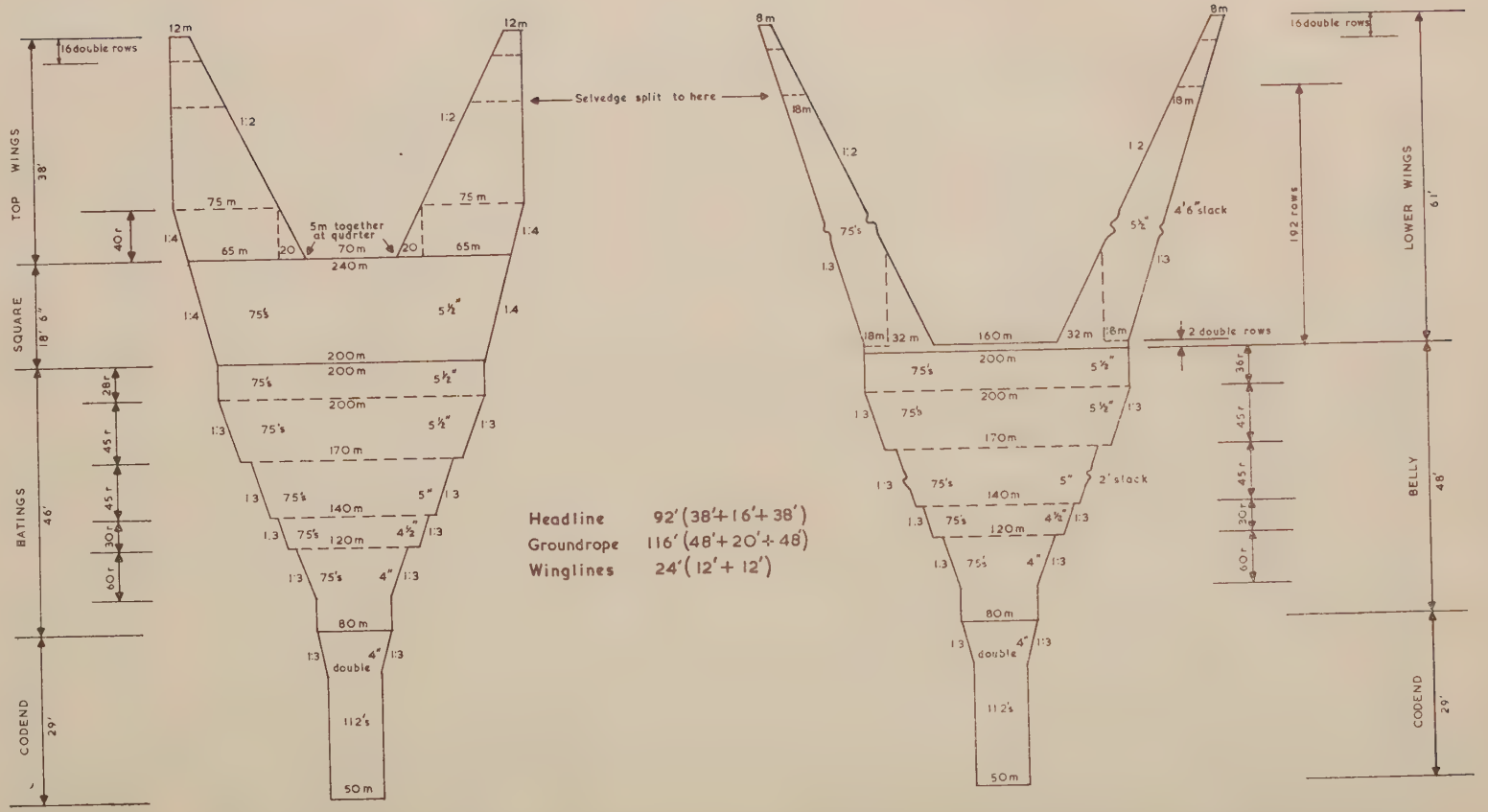

LOWER WINGS
BELLY
CODEND
8 double rows
2 double rows
18"
21"
24"
15"
30"
1'1¾" slack
6" slack
12/24s
double
26m
Scale 0 2' 4' 6' 8' 10'
Headline 20'(7'3"+5'6"+7'3")
Groundrope 29' (12'+5'+12')
Fishinglines (12'9"+5'6"+12'9")
MODEL GRANTON TRAWL
TOP WINGS
SQUARE
BATINGS
CODEND

Fig. 23



REVISED SPECIFICATION FOR GRANTON TRAWL

Fig. 24

MEASUREMENT OF DRAG, SPREAD AND SPEED

Need for these Measurements

he measurement of the drag, spread and speed of the trawling gear is virtually the only study that ɔe divorced from fish catching and considered in a purely engineering way. Why is it important this should be done? The function of the trawl is to catch fish but it must fulfil certain dimensional rements before it can do this. What should these dimensional requirements be? That depends on pecies and size of fish sought, their behaviour and the nature of ground where they are, but the is surely coming when mesh size in the various parts of the net, towing speed, headline height much as possible" isn't a proper answer) can be specified on the basis of more reliable evidence than the moment available. Having specified these dimensions the question of design becomes a purely neering problem, that of ensuring (1) the specification is met, (2) the net is spread to a dimension mensurate with its size, (3) it is strong enough and (4) it matches the power of the boat which has to it. To do this, measurements on the drag, spread and speed of existing standard gear have first to ade. The trawls considered here are (1) the 48 ft Aberdeen net towed by F.R.S. "Explorer", 1200 ; (2) the 30 ft Aberdeen net towed by the old "Explorer", 590 i.h.p.; (3) a 22½ ft net which is a three-ter-sized version of the 30 ft net and is used on F.R.V. "Mara", 204 b.h.p. The models of these three ls were towed by the motor coble.

an of Means" Procedure

he measurements are never reproducible owing to variations in tide, wind and ground so that if the ionship between them is required all have to be recorded at once. Figs. 25 and 26 show that, whether neasurements be made on the full-sized gear or on the model of it, there is a wide scatter of results, ugh the plot of any one run usually follows a sufficiently reasonable curve. The conclusion has been ned that the best way of taking these readings is in the same way as readings are taken in ship trials, by e called the "mean of means". A series of readings is taken towing in one direction with speed in-ing; after the last reading, speed is increased a little more and the ship brought about. The readings hen repeated with speed decreasing. Mean figures are taken. The process is then repeated and the n of means taken. This method not only goes some way towards reducing wind and tide effects but also mizes any hysteresis errors of the instruments. Although this is the procedure that should be aimed is sometimes necessary to make do with less.

lts

ll the results are scheduled in Tables V to X. The drag/speed curves of the 48 ft net and its model lotted in Figs. 25 and 26. Mean figures of drag against speed are plotted in Fig. 27 for all cases dered.

he laboratory no longer has a research vessel on which the normal 30 ft Aberdeen trawl is used, ere is nothing with which to compare the model performance except the few spot readings taken e old "Explorer", as seen in Fig. 2, which may now be compared with Fig. 27. One or two practical s, already referred to, now show up quite well. The 15 h.p. motor coble, even with its towing eller, is hardly fit to tow the quarter-scale model of an arctic trawl, being only able to bring it e scale equivalent of 3½ knots whereas 4½ knots is the new "Explorer's" normal towing speed. On ther hand the model of "Mara's" small net can be pulled at a scale equivalent of 5 knots. At the r end of the model curves steerage way is lost owing to the effects of wind and tide. The tides around rdeen are quite strong and the area is wind swept so that model work of this sort is not done under nost advantageous conditions.

owhere does the drag rise as quickly as the second power of the speed either in the model or full-results. The inference from this is that ground friction forms quite an appreciable part of the total . The agreement between model and full-size drag looks quite good but a glance at the values obtained pread gives cause for reflection.

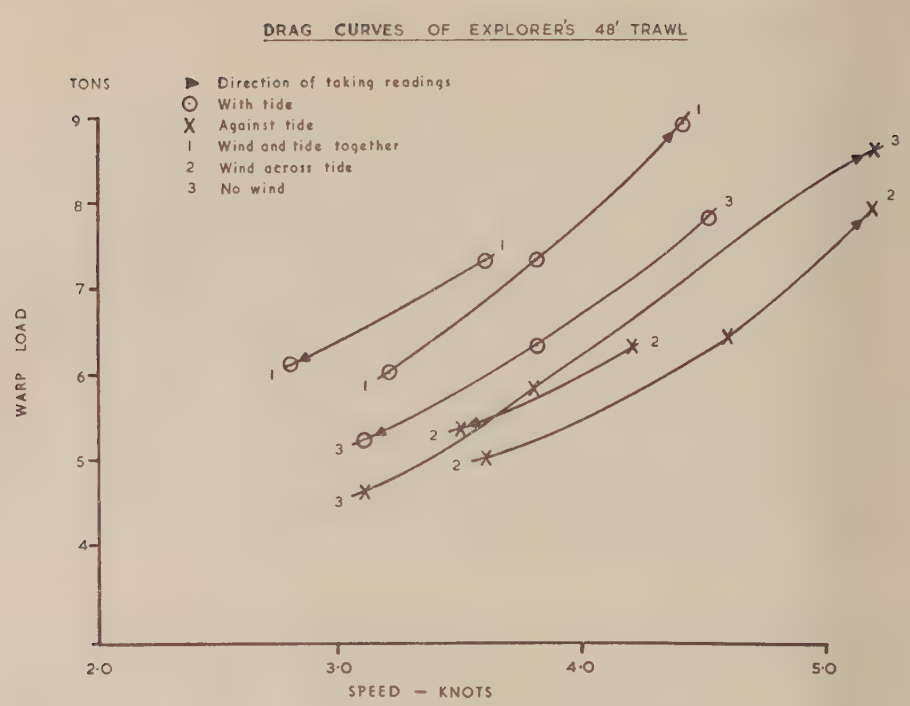

DRAG CURVES OF EXPLORER'S 48' TRAWL
TONS
WARP LOAD
Direction of taking readings
With tide
Against tide
1 Wind and tide together
2 Wind across tide
3 No wind
9
8
7
6
5
4
2·0
3·0
4·0
5·0
SPEED — KNOTS

Fig. 25

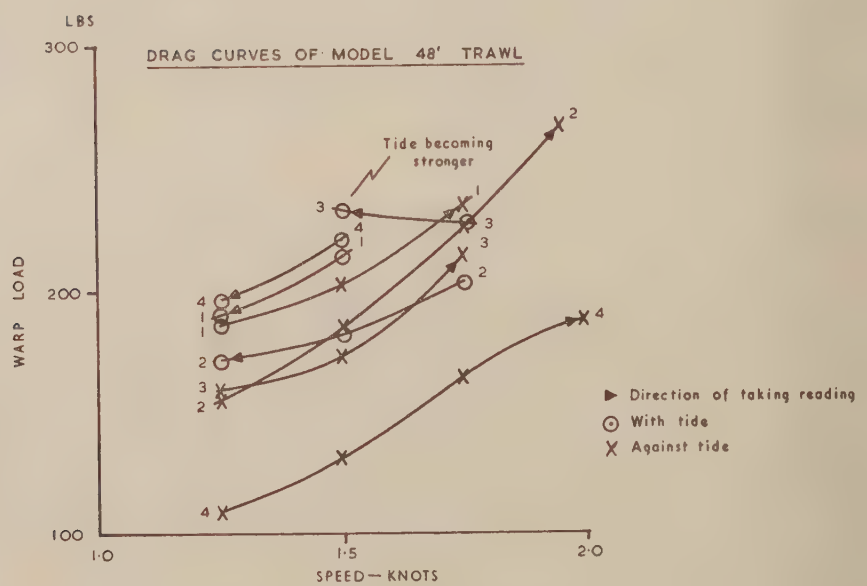

LBS
DRAG CURVES OF MODEL 48' TRAWL
WARP LOAD
300
200
100
Tide becoming stronger
1·0
1·5
2·0
SPEED — KNOTS
Direction of taking reading
With tide
Against tide

Fig. 26

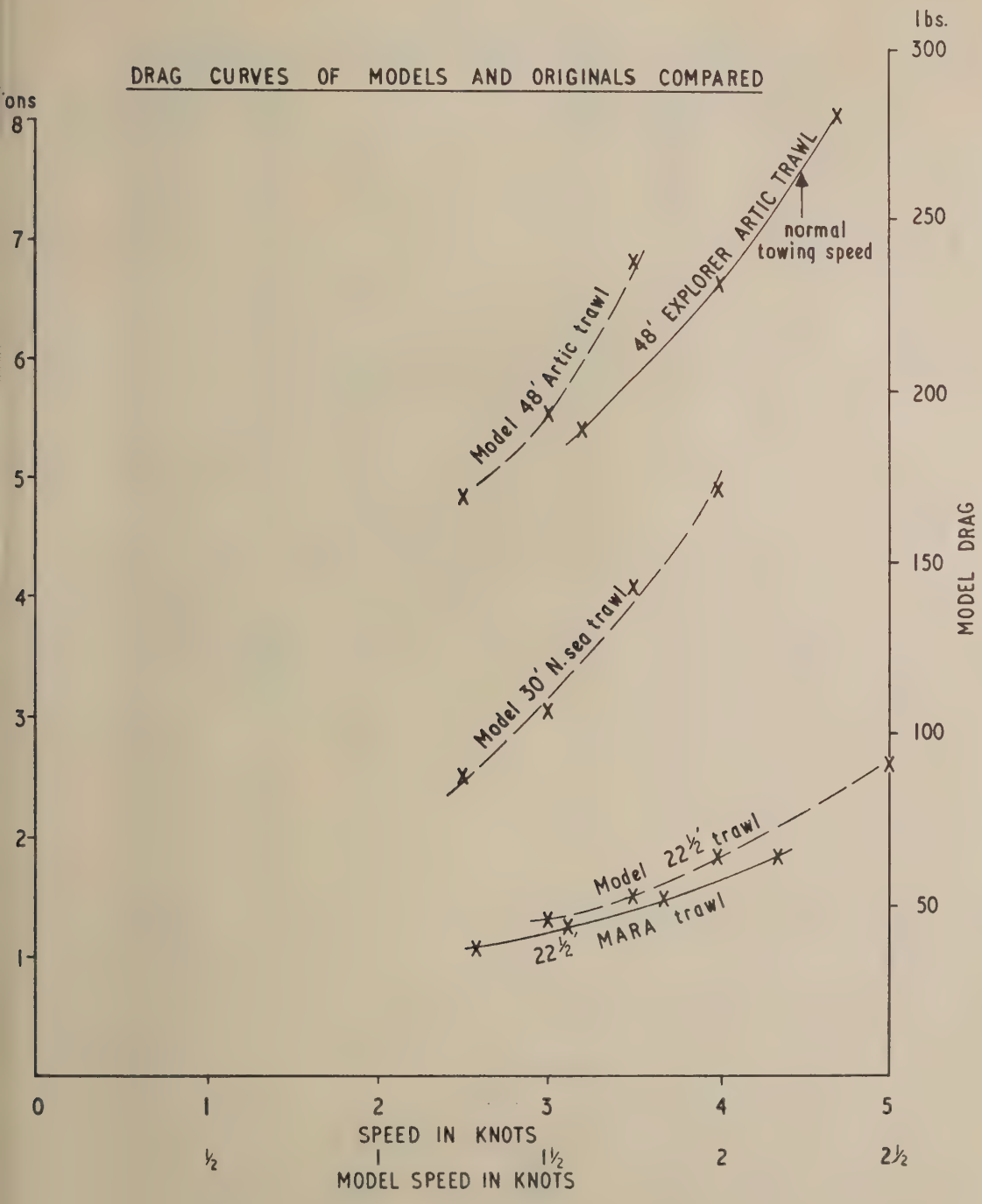

DRAG CURVES OF MODELS AND ORIGINALS COMPARED
lbs.
300
250
200
150
100
50
MODEL DRAG
ons
8
7
6
5
4
3
2
1
Model 48' Artic trawl
48' EXPLORER ARTIC TRAWL
normal towing speed
Model 30' N. sea trawl
Model 22½' trawl
22½' MARA trawl
0
1
2
3
4
5
SPEED IN KNOTS
½
1
1½
2
2½
MODEL SPEED IN KNOTS

Fig. 27

TABLE V

Drag, spread and speed tests

F.R.S. "Explorer" 48 ft net with 15 fm sweeps and 200 fm of warp aft.

	With Tide				Against Tide		
	Speed (knots)	Drag (tons)	Spread (feet)		Speed (knots)	Drag (tons)	Spread (feet)
Haul 1	3·2	6·0	—	Haul 2	3·6	5·0	122
	3·8	7·3	130		4·6	6·4	106
	4·4	8·9	128		5·2	7·9	104
	3·6	7·3	128		4·2	6·3	110
	2·8	6·1	132		3·5	5·3	114
Haul 3	4·5	7·8	106	Haul 3	3·1	4·6	124
	3·8	6·3	116		3·8	5·8	114
	3·1	5·2	116		4·5	7·2	112
					5·2	8·6	104

All in 50-65 fm of water.

TABLE VI

Drag, spread and speed tests

Model 48 ft net with 22½ ft (15 fm sweeps) and 50 fm (200 fm) of warp aft.

	With Tide				Against Tide		
	Speed (knots)	Drag (tons)	Spread (feet)		Speed (knots)	Drag (tons)	Spread (feet)
Haul 1	3·0	6·1	90	Haul 1	2·5	5·3	90
	2·5	5·4	90		3·0	5·8	90
					3·5	6·7	90
Haul 2	3·5	5·8	—	Haul 2	2·5	4·4	—
	3·0	5·2	—		3·0	5·3	—
	2·5	4·9	—		3·5	6·5	—
					3·9	7·6	—
Haul 3	3·5	6·4	74	Haul 3	2·5	4·5	67
	3·0	6·7	80		3·0	5·0	67
					3·5	6·1	64
Haul 4	3·0	6·3	90	Haul 4	2·5	3·1	90
	2·5	5·6	90		3·0	3·7	90
					3·5	4·7	86
					4·0	5·4	86

Haul Nos. 1 and 2 in 5 fm; Haul Nos. 3 and 4 in 15 fm of water.

TABLE VII

Drag, spread and speed tests

F.R.S. "Explorer" (old "Explorer") 30 ft net with 10 fm sweeps and 100 fm of warp aft.

	Against Tide		
	Speed (knots)	Drag (tons)	Spread (feet)
Spot reading only	4	3·1	105

In 20 fm of water.

TABLE VIII

Drag, spread and speed tests

Model 30 ft net with 15 ft (10 fm sweeps) and 25 fm (100 fm) of warp aft.

With Tide			Against Tide		
Speed (knots)	Drag (tons)	Spread (feet)	Speed (knots)	Drag (tons)	Spread (feet)
3·8	5·1	85	2·5	2·3	70
3·5	4·6	83	3·0	2·5	73
3·0	3·6	80	3·5	3·4	80
2·5	2·7	73	4·0	4·3	83

All in 5 fm of water.

TABLE IX

Drag, spread and speed tests

F.R.S. "Mara" 22½ ft net with 15 fm sweeps and 100 fm of warp aft.

With Tide			Against Tide		
Speed (knots)	Drag (tons)	Spread (feet)	Speed (knots)	Drag (tons)	Spread (feet)
2·7	1·0	85	4·3	1·8	80
3·0	1·1	85	3·8	1·6	78
3·2	1·2	78	3·1	1·4	90
3·6	1·3	75	2·5	1·1	90
4·4	1·9	75			

All in 20 fm of water.

TABLE X

Drag, spread and speed tests

Model 22½ ft net with 22½ ft (15 fm sweeps) and 20 fm (80 fm aft).

With Tide			Against Tide		
Speed (knots)	Drag (tons)	Spread (feet)	Speed (knots)	Drag (tons)	Spread (feet)
3·0	2·1	80	5·0	2·1	68
3·5	2·1	76	4·5	1·6	60
4·0	2·5	80	4·0	1·1	60
4·5	2·8	80	3·5	0·9	52
5·0	3·1	84	3·0	0·6	52

All in 5 fm of water.

SSION

the first place it is not the true spread between the otterboards that is being measured but only the d as estimated by the warp divergence at the surface. A few measurements made on the spread of odels, when the otterboards were constricted to a known distance apart, indicated that spread as ated from warp divergence was between 5 and 10% low. Presumably this error is not a constant ut varies with the amount of warp paid out and the length of the sweeps, as well perhaps as with unaccountable factors. Warp divergence is the most sensitive guide that is readily available to ge of circumstances down at the trawl, but it isn't always possible to interpret the changes of spread e correct way. A badly torn net can cause the spread to increase, a heavily loaded one can cause it crease, but other things have their effect too. Towing into shallower water gives an increase of d, turning off a straight course causes a decrease. For both of the full-sized trawls the spread falls e speed is increased, whereas with the models the effect is sometimes the opposite but on the whole erminate. In spite of several attempts, no really satisfactory theory has yet been evolved to relate rag, spread and speed measurements, or to explain the changing relationship between the frictional ydrodynamic forces as speed is increased. However, there is some hope that this may yet be done more instrumentation becomes available at the net end as well as at the ship end. The effects of and tide are pronounced but uncertain and especially so with the models. Having made these

observations and cautionary remarks it appears none the less that the models have a somewhat grea drag and smaller spread than the originals.

Had the models been inaccurately made, in twine that was too thick, then this increase in drag an decrease in spread could have been easily accounted for. An increase in the twine diameter of a net d not give rise to a proportionate increase in net drag, because there is a partial compensation in dr caused by reduction in spread. The twine diameter of the models is, however, correct to within 5%, the basis of calculation at least, so these drag and spread effects look like the first evidence of scale eff that have been obtained. Reviewing this work with the eighth-scale model of the 30 ft net, it may b lucky chance that the twine selected proved to be 22% too thin!

CONCLUSIONS

The observations and measurements made on model trawls have to be correlated with measurem and, where possible, observations on full-sized gear. By the nature of things it is for the most part eas and cheaper to obtain a picture of model performance than performance of the originals but unless th cross-checks are made the value of modelling cannot be established with confidence. There has bee certain amount of luck in the modelling experiments because the application of the modelling rules far evolved has led to closer agreement between model and full-sized results than there was any r reason to expect at the outset. The agreement is not, however, close enough to be accepted uncritical for a significant difference between the performance of models and full-sized originals does appear, models giving the poorer view of gear performance; that is, they are lower in spread and higher in dr The accuracy of the modelling technique is considerably better at quarter-scale than at eighth-scale.

A standard technique for dealing with models has been evolved and a team trained to use it. T treatment includes underwater observations, measurement of the principal operational dimensio underwater photography and measurement of drag, spread and speed at the surface.

Modelling can yield results which would be difficult to achieve in other ways. It can show with fair measure of confidence the effect of alternative methods of rigging a gear and whether their suppo advantages turn out to be real. It can reveal defects in the rigging of gear or setting of a net and leads turn to ideas on how these errors can be corrected. The practical application of fairly simple modell rules is important even if it is not yet accurate to the last degree, because it becomes possible to scale a net up or down in size and weight of material to match another ship of different power and to be fai certain of the operating dimensions, provided those of the original net are known. The limitation that this is only a relative and not an absolute method since it is still necessary to scale from somethi else.

The need is being felt for some more absolute measurements. It is not likely that very much more w be learned about scale effects from experiments in the sea, where accuracy of measurement on mod and originals can be improved but will remain rough. A whole set of experimental data is now requir from which scale effects can be deduced. These data will have to be checked in testing tanks whe sufficient accuracy is obtainable. When this is done it should be possible to design a net, be it model full size, from scratch, predetermining its operational dimensions and drag. There are in short three lev of design, firstly by guesswork, secondly by relative or scaling measurements and lastly by absol methods. At the moment only the second has been reached and there is a natural desire to see the th put in hand. This level, however, requires special test tanks and since a fisheries laboratory does not ha such facilities it must await an opportunity for such data to be produced before it can tackle net desi at the highest level. There now seems good reason to hope that the opportunity is being made.*

There is no need to wait idly, however, for these modelling experiments have provided enough id to keep at least one of our research vessels busy for some time. It has never been the intention to devel modelling as a substitute for other methods of fishing gear testing but rather as an auxiliary to the

*At the time of writing this report, early in 1959, this was all that could be said. A recent press release by the White Fish Autho (February 1960), however, reveals something of the large-scale project, ranging from tank tests to full-scale measurements of trawl sea on "Explorer", now being undertaken under the Authority, by Messrs Saunders-Roe in conjunction with the fisheries scient

dition to the making of underwater observations, other methods based on instrumentation and rative fishing are used both to compare existing rigs of gear and to help in their design and pment. Each method has its limitations. Comparative fishing is the ultimate test but its results e better and more confidently assessed against the fuller picture of gear performance deduced h instrumentation and modelling techniques.

ACKNOWLEDGEMENTS

experiments of the type described in this report could be done without teamwork, and the author of this opportunity to express his thanks to M. J. D. Mowat and J. Main for their work under and above, A. Corrigall, A. Davidson and D. Cattenach for cheerfully mastering a strange job, estley for the same and for his help with photography. Thanks are also due to J. H. Steele for on the theoretical side and for his help in diving. Special mention should be made of the intricate done by G. M. Joss in making the models. To many friends at Lunan Bay, Inverasdale, Mallaig urghead we owe thanks for generous help and for advice on local conditions. The work was not, er, done entirely in small waters and thanks are also due to the commanders, officers and men of search vessels on which the sea trials were conducted.

REFERENCES

nd the Seine Net.' 16mm. Black and white. Sound. Campbell Harper Films Ltd., for Scot. Home Dept.

s in Action'. 16mm. Black and white. Sound. Basic Films for Min. Ag. Fish. and Food.

N, W. 1957. 'The use of model nets as a method of developing trawling gear'. (Presented at Internat. sh. Gear Congr. Hamburg Oct. 1957) F.A.O. Modern Fishing Gear of the World, 166-174, London, shing News (Books) Ltd., 1959.

N, W. 1958. 'Is bang up bang on?' World Fishing, **7**(3), 39-40.

R. W. L. 1943. 'Steering experiments.' Trans. Instn. nav. Archit., Lond., 35-73.

TEIN, S. 1938a. *Modern Developments in Fluid Dynamics,* **1**, sect. 5, p. 16.

1938b. Ibid. **2**, sect. 184, p. 419.

LEV, A. I. 1955. 'Fundamentals of the calculation of the hydrodynamics of trawl boards.' (In Russian). rans. Inst. Mar. Fish. U.S.S.R., **30**, 61-76.

APPENDIX I

List of Twine Runnages Useful in Modelling

All the following twine sizes which it is suggested be used in the construction of models are ch in the absence of detailed knowledge on scale effects. It is therefore likely that some modification subsequently have to be made to this table in the direction of increasing the runnage of the models' t

Greenproofed Manilla s.g. = 1·29
,, Cotton s.g. = 1·34
Unproofed Nylon s.g. = 1·12

Ratio of twine diameters $S_d = \sqrt{\frac{\rho R}{\rho_s R_s}}$

where ρ is the specific gravity
R is the runnage
and subscripts 's' refers to the model.

For $\frac{1}{4}$ scale models where $S_m = S_d = \frac{1}{2}$

$\frac{1}{2} = \sqrt{\frac{1{\cdot}29}{1{\cdot}34}\frac{R}{R_s}}$ where modelling must be done in cotton from original in manila

$R_s = 3{\cdot}85\ R.$

Original in Manila	Requirement in Cotton	Available in Cotton*
60 yd/lb	231 yd/lb	12/27s 245 yd/lb
75	288	12/24s 275
90	346	12/18s 366
112	430	12/15s 440
150	576	12/12s 550
180	692	not available
200	770	12/9s 732

Where the original is in cotton and the model is also in cotton $R_s = 4R$

Original in Cotton	Requirement in Cotton	Available in Cotton
12/36s 183 yd/lb	732 yd/lb	12/9s 732 yd/lb
12/24s 275	1100	32/15s 1180
12/18s 366	1464	32/12s 1470
12/15s 440	1760	40/12s 1830
12/12s 550	2200	36/9s 2220
12/9s 732	2928	not available

Where the original is in nylon and the model is also in nylon $R_s = 4R$

*Cotton runnage is based on a count of 12/12 being 550 yd/lb when twisted in and greenproofed not on the normal unspun, untreated count of 840 yd/lb.

For $\frac{1}{4}$ scale models where $S_m = S_d = \frac{1}{4}$ (i.e. true models)

$\frac{1}{4} = \sqrt{\frac{1{\cdot}29}{1{\cdot}34}\frac{R}{R_s}}$ where the modelling must be done in cotton from the original in manila

$\therefore R_s = 15{\cdot}4\ R$

Original in Manila	Requirement in Cotton	Available in Cotton
60 yd/lb	925 yd/lb	32/18s 985 yd/lb
75	1150	32/15s 1180
90	1385	32/12s 1470
112	1720	36/12s 1650
150	2310	36/9s 2200
180	2770	not available
200	3080	not available

follows that the true quarter-scale models of cotton nets cannot be made in cotton because even gest size of cotton in common use, 12/36s, does not have a scale equivalent at 16 times its runnage. nets would have to be modelled in nylon.

ne scale models in nylon could be made down to an original in 600 yd/lb nylon since 9600 yd/lb is available.

GE OF COTTON TWINES

. 1 Count 840 yd/lb which, spun and greenproofed, runs in to 550 yd/lb

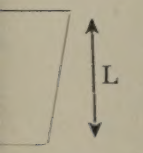
	Unspun and unproofed	Spun and greenproofed
12/36s	280 yd/lb	183 yd/lb
12/27s	374	245
12/24s	420	275
12/21s	480	314
12/18s	560	366
12/15s	672	440
12/12s	840	550
12/9s	1120	732
32/30s	895	585
32/24s	1120	732
32/21s	1280	830
32/18s	1500	985
32/15s	1800	1180
32/12s	2240	1470
32/9s	2990	1960
36/12s	2520	1650
36/9s	3360	2200
40/12s	2800	1830
40/9s	3730	2440

APPENDIX II

AMOUNT OF TWINE IN A NET

Let N be the number of meshes across the top

N



n be the number of meshes across the bottom

m be the mesh size

r be the number of rows in length L

n

ngth of twine in the first row = Nm

„ „ „ „ „ last „ = nm

„ „ „ „ „ sheet $= \frac{N+n}{2} m\, r$

$= (N+n)\, L$ since $r = \frac{2\,L}{m}$

the sheet is square then the length of twine in the sheet is 2 NL or Nmr.

ote that this formula makes no allowance for the amount of twine in the knots and so must be plied by what can be called a knot factor, as given in the Appendix Table 1.

Appendix Table I

Knot Factors for Different Twine and Mesh Sizes

(a) Manila

Mesh in inches	1½	2	2½	3	3½	4	4½	5	5½
Twine									
75s	3·04	2·53	2·22	2·02	1·88	1·77	1·68	1·61	1·56
90s	2·88	2·41	2·12	1·94	1·80	1·70	1·62	1·56	1·51
100s	2·79	2·34	2·08	1·90	1·77	1·67	1·60	1·54	1·49
112s	2·67	2·25	2·00	1·83	1·71	1·62	1·56	1·50	1·45
125s	2·54	2·16	1·92	1·77	1·66	1·58	1·51	1·46	1·42
150s	2·25	1·94	1·75	1·62	1·54	1·47	1·42	1·38	1·34
180s	2·12	1·84	1·68	1·56	1·48	1·42	1·38	1·34	1·31
200s	2·08	1·81	1·65	1·54	1·46	1·41	1·36	1·32	1·30

(b) Cotton

Mesh in inches	1½	2	2½	3	3½	4	4½	5	5½
Twine									
12/9s	1·50	1·38	1·30	1·25	1·21	1·19	1·17	1·15	1·14
12/12s	1·58	1·44	1·35	1·29	1·25	1·22	1·19	1·18	1·16
12/15s	1·67	1·50	1·40	1·33	1·29	1·25	1·22	1·20	1·18
12/18s	1·75	1·56	1·45	1·38	1·32	1·28	1·25	1·22	1·20
12/21s	1·83	1·62	1·50	1·42	1·36	1·31	1·28	1·25	1·23
12/24s	1·92	1·69	1·55	1·46	1·39	1·34	1·31	1·28	1·25
12/36s	2·04	1·78	1·62	1·52	1·45	1·39	1·35	1·31	1·28

(c) Nylon

Mesh in inches	1½	2	2½	3	3½	4	4½	5	5½
Twine									
150s	2·33	2·00	1·80	1·67	1·57	1·50	1·44	1·40	1·36
290s	2·04	1·78	1·62	1·52	1·45	1·39	1·35	1·31	1·28
600s	1·67	1·50	1·40	1·33	1·29	1·25	1·22	1·20	1·18
870s	1·54	1·41	1·32	1·27	1·23	1·20	1·18	1·16	1·15

Printed in Scotland under the authority of Her Majesty's Stationery Office,
by Pickering & Inglis Ltd., Glasgow. Wt. 72161 K.5

rine Research Series continued

959 1. Hydrography of the North-Western Approaches to the British Isles.
By D. S. Tulloch, B.Sc., and J. B. Tait, D.Sc., Ph.D. F.R.S.E. Price 10s. (10s. 4d.)

2. Hydrography of Scottish Coastal Waters.
By R. E. Craig, B.Sc. Price 10s. (10s. 4d.)

3. The Planktonic Stages of the Haddock in Scottish Waters.
By Alan Saville, B.Sc. Price 7s. 6d. (7s. 10d.)

4. Halibut—Observations on its size at First Maturity, Sex Ratio and length/weight Relationship.
By Bennet B. Rae, M.A., B.Sc., Ph.D. Price 7s. 6d. (7s. 10d.)

960 1. The Herring of the Clyde Estuary.
By Henry Wood, M.A., Ph.D., F.R.S.E. Price 8s. 6d. (8s. 10d.)

2. Seals and Scottish Fisheries.
By Bennet B. Rae, M.A., B.Sc., Ph.D. Price 15s. (15s. 4d.)

3. The Scottish Seine Net Fishery, 1921-1957.
By A. Ritchie, O.B.E., B.Sc., Ph.D., F.R.S.E. Price £1 1s. (£1 1s. 5d.)

961 1. Trawl Performance—A Study Relating Models to Commercial Trawls.
By W. Dickson, B.Sc. Price 18s. (18s. 5d.)

Other Fisheries Publications prepared by the Department of Agriculture and Fisheries for Scotland are shown below.

FRESHWATER AND SALMON FISHERIES RESEARCH

A series dealing with freshwater and salmon research under the above heading.

REPORT ON THE FISHERIES OF SCOTLAND

An Annual Report in narrative form containing the report of the Director of Fisheries Research and dealing generally with Scottish Fisheries, including marine superintendence, salmon fisheries and harbours.

SCOTTISH SEA FISHERIES STATISTICAL TABLES

Annual tables giving full information about the weight and value of fish landed, analysed by species, means of capture and areas of capture.

NON-SERIAL PUBLICATIONS

Lobster Storage, by H. J. Thomas . . . . . Price 1s. 9d. (1s. 11d.)

Trout in Scotland, by K. A. Pyefinch . . . . . Price 6s. (6s. 6d.)
(A story of brown trout research at Pitlochry)

(Prices in brackets include postage)

Obtainable from Her Majesty's Stationery Office
at the addresses on page 4 of cover or through any bookseller

© *Crown copyright 1961*

Published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
13A Castle Street, Edinburgh 2
York House, Kingsway, London W.C.2
423 Oxford Street, London W.1
109 St. Mary Street, Cardiff
39 King Street, Manchester 2
50 Fairfax Street, Bristol 1
2 Edmund Street, Birmingham 3
80 Chichester Street, Belfast 1
or through any bookseller

S.O. Code No.